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Editorial Office Address
Polish Academy of Sciences Branch in Lublin
Pałac Czartoryskich, Plac Litewski 2, 20-080 Lublin, Poland
e-mail: eugeniusz.krasowski@up.lublin.pl

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Experimental studies of duration of air pumping out from the "TEAT CUP - PULSATOR" system

Valeriy Adamchuk[1], Vasyl Dmytriv[2], Ihor Dmytriv[2]

1. National Scientific Centre "IAEE"
2. Lviv National Agrarian University, e-mail: dmytriv_ihor@ukr.net

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Abstract. The article analyzes the results of experimental studies of duration of air pumping out from chambers of the variable vacuum-gauge pressure in the "teat cup - pulsator"system.

The study of impact of structurally-technological parameters of milking units on the process of milk ejection and time characteristics of the operating mode was analyzed.

The methods of conducting experimental studies of transitive time characteristics of pulsator operating modes based on differentiated study of transitive processes by high-frequency scanning of vacuum-gauge pressure changes while pumping air out from the "teat cup-pulsator" system are given.

Results of the study of impact of vacuum pressure and the overflow hole diameter on the duration of air pumping out from chambers of the variable vacuum-gauge pressure system are provided. Results of experimental data are compared with theoretical ones. The analysis of results of experimental studies showed that the pulsator overflow hole diameter has the greatest effect on the duration of air pumping. By reducing the diameter, the duration of air pumping increases nonlinearly.

Due to results of comparison of theoretical and experimental studies it was found the deviation of experimental data from the theoretical modeling of the duration of air pumping out from chambers of the variable vacuum-gauge pressure in the"teat cup - pulsator"system.

The coefficient of coordination of theoretical dependencies on experimental data to calculate the duration of air pumping was calculated.

The analysis of the obtained dependencies of the duration of air pumping out from the system "teat cup - pulsator"system allowed to recommend the most rational options of the pneumatic and electromagnetic pulsator, provided that it will be provision of the mode of smooth shockless opening of milking cup teat rubber at 48 kPa vacuum pressure and the volume of variable vacuum-gauge pressure chambers of the system "teat cup - pulsator" 10^{-4} m^3.

Key words: milking unit, pulsator, vacuum-gauge pressure, pumping duration, isolines.

INTRODUCTION

One of the problem concerning machine milking today is the disparity of operating parameters of milking units in physiological characteristics of milk ejection. This prevents rapid and complete milking. Today most advanced technical means to ensure "clean" machine milking (hand milking - not exceeding 100 g), do not provide whole cows milking (about 3 liters of alveolar milk is left in the udder)[1].

Therefore, the question of milking units improving remains an urgent problem.

One of the important components of the technological process of machine milking is a milking unit, which has a direct impact on labour productivity and intensity of milk ejection and animal health. Largely, parameters and characteristics of milking unit operation depend on the pulsator technical level.

In automated (robotic) systems milking pulsator is crucial for the realization of adaptive milking process control algorithm [2]. Thanks to these, you can achieve the regime of milking in a function from the intensity of milk ejection for each cow udder quarter by choosing the operation algorithm for functional pulsator adaptation to each teat.

Defining of reasonable pulsator structurally-technological parameters allows to control regime milking unit characteristics and stimulate milk ejection, to increase productivity and prevent the harmful effects of machine milking on a cow.

The given problem is solved provided that the adaptive pneumatic and electromagnetic pulsator, which is installed directly on the milking cup that provides adaptive mode of the teat cup of each individual udder quarter, is applied. The aim of the experimental research was checking of conclusions rightness made during theoretical [3; 4] researches.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Works of many researchers are dedicated to the study of the impact of structurally-technological parameters of milking units on the process of milk ejection [1-15].

In particular, A.I. Fenenko investigated changes of vacuum-guage pressure for the milking unit DA-F-50 if the speed of milk ejection was 0-4 kg /min and there were structural sizes of operating mechanisms[5, 6].

The proposed by L.A. Kiriavtsev schematic diagram of the milking unit, which ensures the independence of milking cups operation apart with regulators of milk ejection, enables automatic change of operating mode of each milking cup of milk depending on milk ejection of the corresponding quarter of the udder and better adaptation of the milking unit to physiological requirements of milk ejection [7].

Investigating the operating process of modern automated milking units, V.T. Dmytriv developed the system of milk unit self-setting parameters according to the physiology of cow's milk ejection [9-11]. The block diagram of the automated milking unit, which allows implementing the algorithm of self-setting parameters, is shown in (Fig. 1).

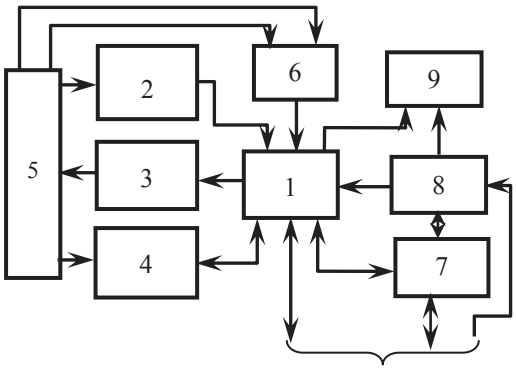

Fig. 1. The block diagram of the automated milking unit:

1 – single chip computer; 2 – thermoanemometric indicator of milk ejection intencity; 3 – electronic pulsator; 4 – complexindicator of milk parameters (pH, temperature); 5 – milking (teat) cup; 6 – pressure sensor; 7 – multiplexer interface of digital information coding / decoding; 8 – unit of stabilized voltage; 9 – information display unit.

The implementation of such a system improves the performance of both technical and biological systems and optimization of technological process of machine milking in general, by milking unit parameters setting according to cows milk ejection, which solves the problem of subsystem "machine-animal" adapting and ensures the implementation of the system of "exact livestock raising" [9-14].

V.F. Uzhyk and A.A. Belokobylskyy while developing and justifing structural and operational parameters of milking units with controlled operating mode studied changes of vacuum-gauge pressure in the governing chamber according to the time when switching from the stimulating milking mode to the nominal one depending on the diameter of the calibration hole, the air flow through the calibration hole of the governing chamber valve and the pressure drop on it [15-17].

After analyzing the study, we should note that despite of considerable extension of pneumatic and electromagnetic pulsators of milking units, improving their constructive and technological characteristics, issues on adaptation of constructive and technological parameters to milk ejection of a cow remain unexplored and unresolved.

OBJECTIVES

The purpose is to study the duration of air pumping out from chambers of variable vacuum-gauge pressure of the system "teat cup - pulsator" for providing the shockless closing and opening of the teat cup rubber.

METHODS

According to the developed methods[18] it was conducted the planned experiment of studying of duration of air pumping in the "teat cup - pulsator"system. The main factors affecting the pumping duration are the vacuum-gauge pressure P_i, the diameter of the hole d_{nep} through which the space of chambers of variable vacuum-gauge pressure of the system is filled with the air, and the volume of chambers of variable vacuum-gauge pressure remained unchanged. To obtain the mathematical model of the experiment the noncompositional Box-Behnken design of the second order on three levels with five times repeatability of experiments was conducted. Selection of factors limits were done on the basis of real operating modes of a milking unit and according to the results of theoretical studies [19, 20]. Thus, the vacuum-gauge pressure varied from 40 kPa on the lower level to 48 kPa at the upper level with a variation interval of 4 kPa, the diameter of the overflow hole d_{nep} - from 2 mm on the lower level to 4mm on the upper level with a variation interval of 1 mm.

Coefficients of the regression equation were calculated and given for natural values of factors. The regression equation describing the dependence of duration t of air pumping out of chambers of the variable vacuum - gauge pressure on vacuum-gauge pressure P_i and the diameter of the overflow hole d_{nep} in natural values is:

$$t = 1{,}8184 - 0{,}0752 \cdot P_i - 0{,}03 \cdot d_{nep} - \\ - 0{,}00135 \cdot P_i \cdot d_{nep} + 0{,}001 \cdot P_i^2 + 0{,}0014 \cdot d_{nep}^2 \quad (1)$$

Checking of reproducibility of experiments was done by comparing tabular G_T and calculation G_P values of the Cochran′s test. As the condition $G_p \le G_T$ was fulfilled [18; 21] – the experiments were reproducible.

The significance of the regression coefficients were tested due to Student's t test (t-test) for the selected index of significance (0.95) and the degree of freedom [21]. After comparing each factor, it was concluded that all coefficients were significant.

Regression equation suitability to describe the real

depending of the optimization criterion on factors was performed by using the Fisher′s test (F- test) according to known methods [21-23] of conditions (2).

$$F_p \le F_T \text{ – the adequate model;}$$

$$F_p \ge F_T \text{ – the model is not adequate,} \quad (2)$$

where: F_T – tabular value of the F-test for the degree of freedom of the main dispersion f_1= 3 and dispersion adequacy f_2= 36 is F_T = 2,9 [21; 22; 23]; F_p – the calculation value of the Fisher′s test will be equal F_p = 0,1163.

Taking into account that $F_p \le F_T$, we can state with 95% probability that this model is adequate.

Graphically, the regression equation is represented as a three-dimensional plane and shown in (Fig. 2).

It was important to assess the impact of vacuum-gauge pressure P_i and the diameter of the overflow hole d_{nep} on the duration t of air pumping out of chambers of the variable vacuum-gauge pressure of the "teat cup-pulsator"system.

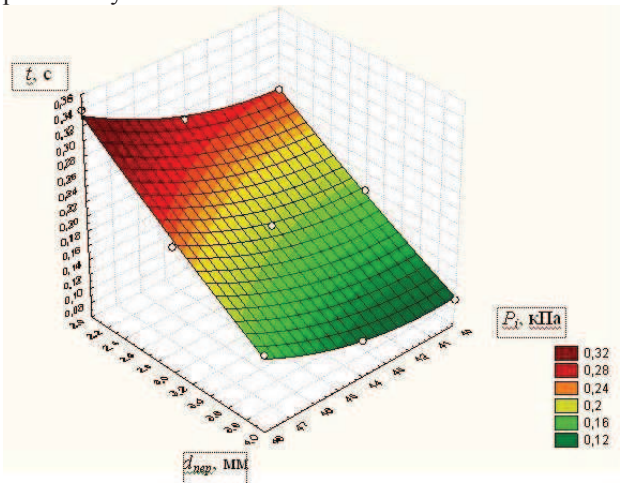

Fig. 2. Dependence of the duration t of air pumping out from chambers of the variable vacuum-gauge pressure of the "teat cup-pulsator"system on the diameter of the overflow hole d_{nep} and the vacuum-gauge pressure P_i.

To build isolines on the factor plane (x_1, x_2), the regression equation was solved (1) as a quadratic equation. Building of isolines was done using the following algorithm:

a) we chose several sections of the factor space (usually 6 sections are sufficient if x_1 = 0; x_1 = ±1; x_2 = 0; x_2 = ± 1);

b) by substituting into the equation the functions of values recall 0, ± 1 for one of the factors x_j (j = 1,2) were found for each intersection of the equation after bringing similar terms:

$$y(x_j) = b_0' + b_i' \cdot x_i + b_{ii} \cdot x_i^2 \ (i = 1,2). \quad (3)$$

a) we found a solution to this equation:

$$x_i(x_j) = -\frac{b_i'}{2b_{ii}} \pm \sqrt{\frac{1}{b_{ii}} \cdot \left\{ y(x_j) - \left[b_0' - \frac{(b_i')^2}{4b_{ii}} \right] \right\}}. \quad (4)$$

d) we substituted the values $y(x_j)$=y_c for a given isoline in the equation of the intersection, and determined the coordinates of the appropriate intersection points with the intersection x_j.

THE MAIN RESULTS OF THE RESEARCH

Results of construction of two-dimensional sections of the response function are shown in (Fig. 3).

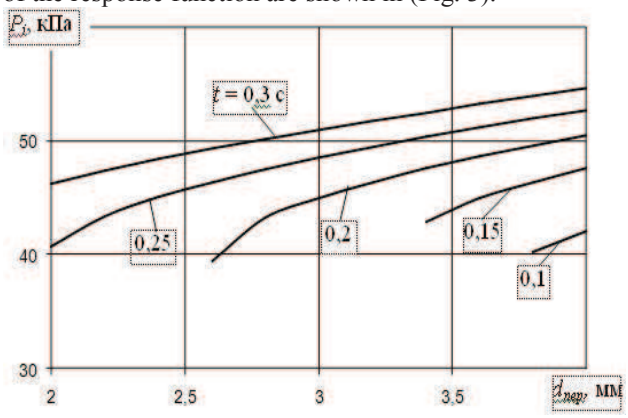

Fig. 3. The impact of vacuum-gauge pressure P_i and the diameter of the overflow hole d_{nep} on the duration t of air pumping out from chambers of the variable vacuum-gauge pressure of the "teat cup-pulsator"system.

Analysis of the obtained surfaces showed that the diameter of the overflow hole had the greatest impact on the duration of air pumping. If we reduce it, the duration of air pumping increases nonlinearly.

When comparing the theoretical and experimental results of the research (Fig. 4), some deviation was detected.

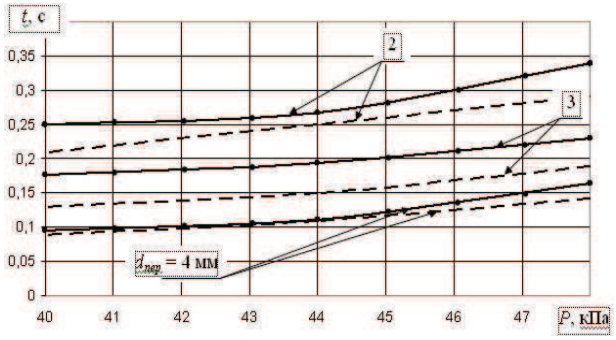

Fig. 4. Dependence of the duration t of air pumping out from chambers of the variable vacuum-gauge pressure on the vacuum-gauge pressure P_i and the diameter of the overflow hole d_{nep}.

Thus, the deviation of experimental data from the theoretical modeling [3] of duration of air pumping out from chambers of the variable vacuum-gauge pressure of the "teat cup-pulsator" system is in the range from 0.2% to 26.4%. When the vacuum-gauge pressure was P_i = 40 kPa and the diameter of the overflow hole d_{nep} = 2 mm, the deviation of theoretical datas from experimental ones was 22.4%. When the vacuum-gauge pressure was P_i = 48 kPa and the diameter of the overflow hole d_{nep} = 2 - 4 mm, the deviation of theoretical data from experimental ones was 13 - 17.8%.

This is because when calculating the duration of air pumping with the use of the mathematical model while modeling the speed coefficient, the mode of air flow through the overflow hole was chosen approximately and the pressure loss coefficient was calculated with deviations, which led to the deviations of theoretical data from experimental ones.

To coordinate theoretical dependences with experimental data we enter the coeficient 1.18 into the equation of modeling of duration of air pumping out from chambers of the variable vacuum-gauge pressure of the "teat cup-pulsator"system.

CONCLUSIONS

The results of experimental studies confirmed the theoretical studies. It was established that duration of air pumping out from chambers of the variable vacuum-gauge pressure of the "teat cup-pulsator"system increased with reducing of the diameter of the pulsator overflow hole d_{nep}, and with increasing of vacuum-gauge pressure.

Analysis of the obtained dependencies enables to recommend rational parameters of pneumatic and electromagnetic pulsator providing the shockless smooth closing and opening of a teat cup rubber at the vacuum-gauge pressure P_i = 48 kPa and the volume of chambers of variable vacuum-gauge pressure of the "teat cup-pulsator"system" $V = 10^{-4}$ m^3.

For the duration t of air pumping out from chambers of the variable vacuum-gauge pressure set in the range of 0.16 to 0.17 s, the diameter of the pulsator overflow hole must be within d_{nep} = 3-3,2 mm.

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Effect of engineering factors of the land plot on the efficiency of its use in the event of division

Alexandra Kovalyshyn[1], Nadia Kryshenyk[1], Pshemuslav Len[2]

[1]Lviv National Agrarian University; e-mail: nadya_kryshenyk@ukr.net
[2]University of Engineering and Economics in Rzeszów;e-mail: geo.pl@wp.pl

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Abstract. The article analyzes the efficiency of land plot use in the event of its division based on engineering factors.

The concept of a land plot and the process of its devision was determined. It was established that the division of land is made at the owner′s desire to separate one or more individual land plots. Thus, the land plot is considered to be divided into parts if each of the parts determined after devision may become a separate plot with further effective use of each of them.

The possible options for the division of land were analyzed. It has been found that division (unification) of the land plot is made by developing of the technical documentation on land management concerning the division and unification of the land plot. It is possible to carry out this procedure only when the right to land is legalized.

On the basis of experimental studies it was found that newly formed land plots became less compact in configuration after the division which affects the efficiency of their use.

Therefore, it is necessary to develop common methods of land devision that will provide its effective use without creating inconvenience to the owners of land plots.

Key words: land plot, land division, technical documentation on land management, compactness coefficient, land owners, land use.

INTRODUCTION

In terms of urban agglomeration division of land between different land owners and land users becomes increasingly important.

The division of land may be carried out for different purposes. In the vast majority it should be done when there is a need in the implementation of civil contracts regarding not the whole area, but its individual parts.

Nowadays in Ukraine clear land devision or unification techniques have not been fully established yet as well as limit values of areas and forms of plots, which are formed as a result of these actions, have not been defined.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Division and unification of land are enlighted in many legal acts of Ukraine [1, 2, 5, 8]. Also, a number of works of domestic and foreign scientists, including works of Yu.V.Gudkov, M.I.Krasnova, V.A.Riabchij, M.F. Stepanenko, A.M. Tretiak and others are devoted to this issue. They highlighted the theoretical principles of land division but the question of determining the effectiveness of their use after the division needs further study.

OBJECTIVES

The purpose of this study is to analyze the effect of engineering factors of the land plot on the efficiency of its use in the event of devision based on comparison of the compactness coefficient before and after devision.

THE MAIN RESULTS OF THE RESEARCH

Land - is a part of the earth's surface with established boundaries, certain location, and defined rights on it [1].

The division of land is made at the owner′s desire to separate one or more individual land plots. Thus, the land plot is considered to be divided into parts if each of the parts determined after devision may become a separate plot with further effective use of each of them.

The division of land is carried out through the development of technical documentation on land management concerning the division and unification of the land plot. It is possible to carry out this procedure only when the right to land is legalized.

Development of technical documentation on land management consists of the following stages:

1. Forming the grounds for the development of technical documentation on land management - an application of the land owner or land user.
2. Carrying out survey works.
3. Getting the technical task for the development of documentation on land management in the local body of National land agency and its approval.
4. Development of the technical documentation on land management concerning the division of the land plots.
5. Determination of the cadastral number (s) of the land plot.

6. Registration of the property right to the land plot by the territorial administration of the registration service and making of the title document on land.According to the Law of Ukraine "On Land Management" [2] the technical documentation on land management concerning the division and unification of land plots includes:

a) the explanatory note;

b) the technical task for development of documentation approved by the client of the documentation;

c) the cadastral plans of land plots, which are combined into one land plot, or a part of the land plot that is distinguished as a separate land plot;

d) the materials of field geodetic works;

e) the deed of conveyance of landmarks for retaining while deviding the land plot according to the boundaries of devision;

d) the list of encumbrances of land rights, restrictions on its use and available land easements;

f) notarized consent to the devision or unification of the land plot of mortgagees, users of land (in case if land is mortgaged or in use);

g) consent of the land owner for lands of state property - the body authorized to carry out the disposal of the land plot,on division or unification of land plots by the user (except cases of division of the land plot in connection with the acquisition of ownership of a house located on it).

Such land plots are subjects to devision: devolved to several heirs; belonging to two or more persons on the right of joint ownership; formed as a result of the contract of donation of the land plot to several persons; the purpose use of the land plot changes and so on.

There are following options for the division of the land plot in the scientific literature [3]:

1. The best option - when the buildings stand apart. There are two separate passages and entrances to buildings of both owners, no common parts of buildings, structures. In this case, the land plot can be called "divisible".

2. Under situational conditions of placement of buildings on the land as to the street, some passages are not only absent, but they cannot be made. In this case, it is proposed to divide the land into three parts.

Two separate plots are only for the seller and buyer and one general - in their joint lease or joint property for passage and so on. In this case, this land plot can be called "partially divisible."

3.According to the mutual location of buildings, structures, the land plot cannot be devided at all. For example: the first floor belongs to the seller, and the second - to the buyer. In this case the only possible thing is a joint lease. A rent for the lease of the land plot provided in a joint lease,should be determined in proportion to shares (areas) of real estate owned by the seller and the buyer. This land plot is called "indivisible".

Every option of the possible division of the land plot affects the efficiency of its use.

The effectiveness of the reorganization of the land plot can be seen in various aspects. One of them is an engineering aspect – effect of the configuration of the land plot on the effectiveness of its division. Under the configuration of the land plot we understand the external outline (contour) of the land plot with mutual location of turning angles.

A.M. Tretiak proposes to hold assessment of the configuration of the land plot using the compactness coefficient of the territory [4]:

$$Cc = \frac{P}{4\sqrt{S}}, \qquad (1)$$

where: Cc – the coefficient of compactness of the territory, P – the perimeter of the land plot , S – the area of the land plot, m^2.

After calculating the authors believe that "the closer the compactness coefficient to the number one , the better the configuration of the land plot". Thus, the coefficient of compactness is a quotient of devision of the perimeter of certain ownership and land tenure by the perimeter of the square of the same area as the figure that has the smallest perimeter.

Dependence of the compactness coefficient of the territory on the perimeter is shown in the graph (Fig. 1).

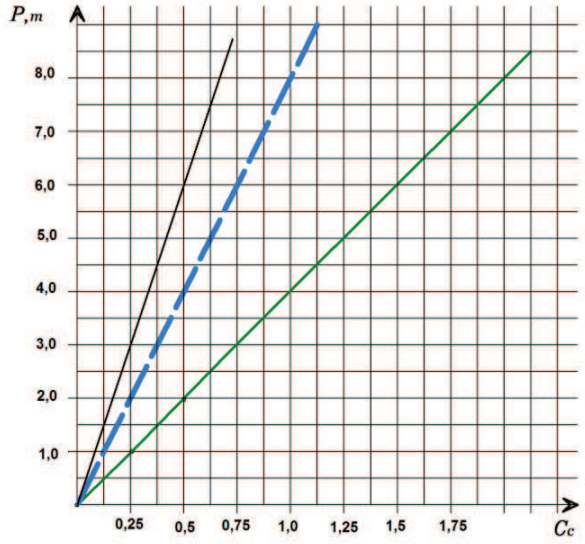

Fig.1. Dependence of the compactness coefficient of the territory on the perimeter of the land plot*.

** Source: developed by the authors.*

That is, the most compact configuration of the land plot is in the form of a square.

Experimental data affirm changes of the compactness coefficient of the land plot before and after its division, and this has an effect on the efficiency of its use.

For example, let us consider the land plot, which is located in the western part of the city Lviv (Fig. 2).

A characteristic feature of the area which is under study is that land plots of the square configuration are met here very rarely, and the most prevailing ones are rectangular plots of arbitrary length and width.

The total land area of the studied plot is 0.0681 ha (Fig. 3).

The vehicle entrance is available from Levandivska street. In the process of land use there was a need in its division between two heirs. Since the conventional methods of devision of land plots are absent, the division is made at the owners′ desire.

(Fig. 4) shows a plan of division of the land plot among heirs. According to the will inherited shares of the territory are equal.

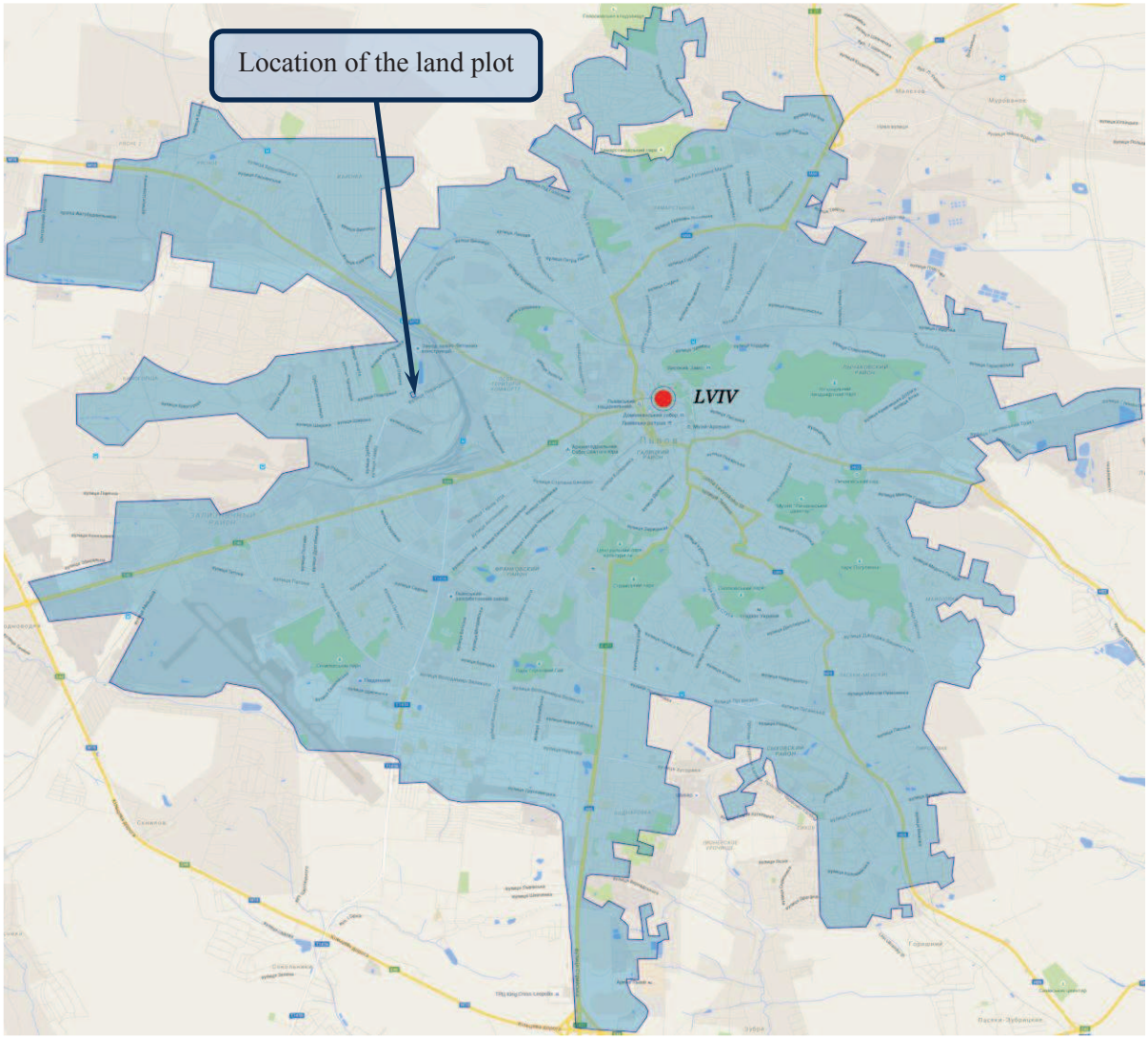

Fig. 2. Location of the land plot*.
**Source: developed by the authors on the basis of Google Map.*

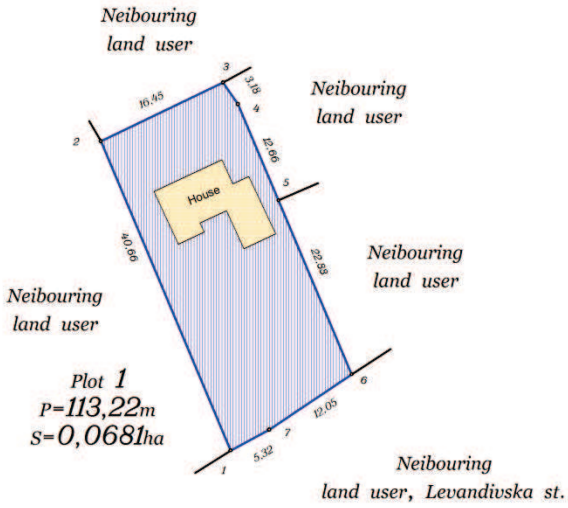

Fig. 3. Plan of the land plot in Levandivska street*.
**Source:developed by the authors.*

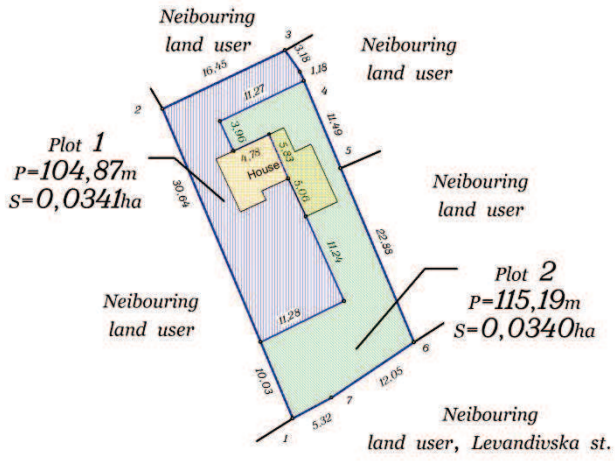

Fig.4. Plan of the land plot devision in Levandivska street*.
**Source:developed by the authors.*

(Table 1) shows the characteristics of the land plot in Levandivska street before and after devision.

Table 1. Characteristics of the land plot in Levandivska street

Number of the land plot	Form of the land plot	Number of turning angles of the land plot boundaries	Perimeter, *P*, m	Area, *S*, ha
Before devision				
Plot 1	Approximate to the rectangular	7	113,22	0,0681
After devision				
Plot 1	Polygon	12	104,87	0,0341
Plot 2	Polygon	13	115,19	0,0340

According to the performed data we calculate the compactness coefficient of the territory.

Before division:

$$Cc\ plot\ 1=\frac{113,22}{4\sqrt{681}}=1,08. \quad (2)$$

After devision the compactness coefficient of the territory for two plots is:

$$Cc\ plot\ 1=\frac{104,87}{4\sqrt{341}}=1,42, \quad (3)$$

$$Cc\ plot\ 2=\frac{115,12}{4\sqrt{340}}=1,56. \quad (4)$$

So, after the division the newly formed land plots became less compact in configuration.

The division of the land plot in Levandivska street in accordance with the plan of devision is impractical. First of all, it is connected with the compactness coefficient of the land plots, which changed from 1.08 - for general territory to 1.42 and 1.56 - for some of its parts. Also unreasonableness of this division is that the newly formed land №2 has an awkward shape and broken lines complicating its use for the intended purpose – for construction and maintenance of residences, farm buildings and structures.

CONCLUSIONS

So, on the basis of the experimental studies it was defined that after the division the newly formed land plots became less compact in configuration, which affects the efficiency of their use.

Modern conditions of land market functioning require from lawmakers improvement of existing and adoption of new standards. It is necessary to develop convential methods of devision of the land plots that will ensure their effective use without creating inconvenience to land owners and land users. These methods also should provide the size of the minimum allowable area of the land plot for a specific intended use.

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Higher education in Ukraine: search for development models

Denys Zagirniak

Volodymyr Dahl East-Ukrainian national university; e-mail: deniszagirnyak@rambler.ru

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Abstract. The amount and profoundness of market reforms convincingly testify to extensive qualitative transformation in the field of higher education of Ukraine. Effectiveness of promotion along the way of reforms has provided the necessity for determining the coordinates of the state of Ukrainian higher school in relation to classical models of higher education and contemporary tendencies of development of the world educational space. Government bodies and social institutes in Ukraine tried to create conditions for civilized business in the field of higher education. At the beginning of reformation higher education operated according to the continental model. Transformation of relationship at the level of principles inevitably caused changes in Ukrainian society on the whole. The Atlantic model was chosen as a development vector but, due to inertia, Ukrainian higher education did not attain complete conformity with this model. Reformation results indicate that withdrawal of Ukrainian higher education from the continental model will take a lot of time.

Key words: higher education**,** reforms, Atlantic model, continental model, higher educational establishments.

INTRODUCTION

Free higher education (hereinafter – HE) was considered one of prominent achievements of socialism in the territory of modern Ukraine during more than seven decades of the previous century. This circumstance is to be analyzed not as much as a ponderable argument in political confrontation with the West but, first of all, as a social and economic precedent that was a big challenge to developed capitalistic countries. Increase of the amount of government funding of HE in Western European countries after World War II should be regarded as manifestation of socialization of public development, which gained significant scale in particular countries in the course of time and later the powers and the public considered it as an important feature of the standard of living.

In the 90s of the previous century Ukraine chose capitalistic vector of development, which, undoubtedly, related to the field of higher education (hereinafter – FHE). It should be admitted that commercialization of HE considerably fell behind material production and other branches of social sphere. Also, later, commercialization of the activity of higher educational establishments (hereinafter – HEE) was not taken unambiguously positively by the society. Obvious Ukrainian higher school development lag from countries- leaders of the educational space does not cast doubt upon the correctness of the choice of the development vector. The number and profoundness of the performed reforms present a convincing evidence of extensive qualitative transformation in FHE. Under the circumstances the effectiveness of promotion along the path of reforms depends on correctness of determining the coordinates of the state of Ukrainian higher education in relation to classical models of HE and modern trends of development of the world educational space.

THE ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

FHE specialists on both coasts of the Atlantic Ocean worry about problems concerned with increase of commercialization of universities activity. So, D. Bok is anxious about retention of the quality of education in American universities under the condition of commercialization [1]. M. Shattock shares his experience of management of commercially successful universities [2]. R. Geiger apposes knowledge and money and analyzes research universities and market paradoxes **[**3]. E. Neborskyi studies the phenomenon of capitalization of US universities [4]. D. Urbano and M. Gerrero regard social and economic consequences of academic entrepreneurship in Europe from the point of view of entrepreneurial universities [5]. H. Goldstein and D. Drucker prove the universities influence on the level of economic development of regions [6]. It should be stated that Western specialists do not take entrepreneurship in FHE unambiguously. On the one hand, inevitability of commercialization is understandable; on the other hand, there is longing to preserve academic values as a guaranty of realization of universities' cultural mission.

Ukrainian specialists thoroughly investigate the essence of commodity-money relations of FHE subjects. So, I. Pasinovych extended theoretical principles of HE government regulation from market positions [7]. L. Tsymbal analyzes basic problems of higher education services (hereinafter – HES) market functioning [8]. O. Romanovskyi considered features of commercial academic activity of entrepreneurial universities [9]. Contemporary state, trends and problems of development of HES market are researched by N. Mospan and

S. Kucherenko [10; 11]. O. Karpiuk developed theoretical-methodical principles and practical approaches to the research of regional HES market [12]. O. Dubrovka regards non-commercial marketing as an instrument of HE government management [13]. Ukrainian specialists try to thoroughly investigate the nuances of market mechanism functioning in FHE. It should be admitted that, on the one hand, they reveal the essence of market relations for themselves, and on the other hand, they are direct participants of their formation.

General problem parts not solved before. Judging by extension and scale of changes, during the recent quarter of a century Ukrainian higher school has covered the path that Western educational systems covered during centuries. The reforms resulted in the fact that modern Ukrainian HE acquired features reflecting the wish to preserve best traditions and national originality and also to learn all progressive aspects of the world educational community. So, for further development it is necessary to find out to what extent this symbiosis meets classical models of higher education.

OBJECTIVES OF THE PAPER

To find out the coordinates of the contemporary state of Ukrainian higher school in relation to recognized models of higher education by comparison of the features inherent in Ukrainian and foreign educational systems, which will make it possible to determine the vector, ways, methods and forms of further reforms.

THE MAIN RESULTS OF THE RESEARCH

S. Kucherenko states that national educational systems develop according to social-economic and political conditions specific for each country [11, p. 21]. E. Neborskyi emphasizes that all HE systems have common features and particularities, but they are organized differently from the point of view of social-economic terms. [4, p. 4]. It is the path of factors influence and life cycle of conditions that determine the interval situation [22, 23]. So, the interval situation is characterized by features inherent in national FHE. The initial condition of assessment of Ukrainian HE features – opposition of the Atlantic (liberal) and continental (European) educational model, that is the least engaged, was proposed by V. Vahstein [14].

Recently the continental educational model has been used by most part of higher educational establishments in Europe, and universities of Germany, the Netherlands and Switzerland were its ardent advocates. This model is distinguished due to typological features. One of them consists in direct government regulation of the activity of higher educational establishments. Determining the essence of HES market, most specialists emphasize its special status in the society. O. Karpiuk states that important market functions provide positive externalities for the third persons and for the society as a whole [12, p. 4, 5]. L. Tsymbal emphasizes the special significance of education for society development, which requires combination of the government and market mechanisms of realization and regulation. In her opinion, market balance is achieved due to priority of the government regulation in relation to the market mechanism that has functions of providing flexibility and diversity when meeting people's demand for educational services [8, p. 7, 10]. N. Mospan is sure that market should not only perform government tasks but also meet constantly growing social demand for education, increase the educational level of economically active people [10, p. 147]. Affirming that provision of HES is inevitable, I. Pasinovych is convinced that its prudence, predictability, leveling of destructive influence and promotion of improved compatibility of Ukrainian HE system depend on the state [7, p. 10].

The special status implies considerable government regulation of FHE. Modernization of education management system stated in the National strategy of education development in Ukraine for the period up to 2021 provides development of a model of government-public management in the field of education. In this model a person, the society and the state become equal subjects and partners [15]. According to paragraph 2 of clause 3 of the Law of Ukraine "About higher education" (hereinafter – Law 1) government policy in FHE is based on the principle of promotion of government-private partnership in FHE [16]. So, the state is worried about the condition and development of FHE. On the one hand, commodity-money relations are not excluded in this field, on the other hand, the state is entitled to direct, regulate and control relations in it. State care is to defend the interests of the society and the person under market economical conditions. In this context O. Dubrovka calls optimization of commercial and sociocentric orientation of HES market the basic method of its governmental regulation [13, p. 10]. Among characteristic features of market organization of education I. Pasinovych designates a public-government system of management [7, p. 10].

The attitude of Western specialists to the role of the state in FHE is different. R. Geiger attributes performance of the task of social coordination to the market. Market coordination as an antithesis to the government one enables coordination of the social role of higher educational establishments. Market coordination, actions of the government, charitable organizations and public associations of universities are of great importance in FHE. In this connection the author is concerned with the problem of the market role in social coordination of HEE and its variation in the future [3, p. 232, 233]. R. Geiger prefers market forces in coordination of HEE activity. E. Neborskyi points out the specific feature of HE in performance of social functions: person's realization and self-development, creation of communes according to interests. In this context education is a source of adequate development and a vital organ of society. As a social institute, a university is to be a mediator between the society and science. The institute created by the state to meet social needs rises over social groups. The necessity for government regulation appeared in the middle of XX century with the aim of science stimulation, development of universities and control of tasks performance. Nowadays one of the basic directions of educational policy consists in development and improvement of lending system [4, p. 8, 9, 37, 39, 40, 42, 43].

So, the special status of education in the society is recognized by both Ukrainian and Western specialists. However, while Western scientists insist on the priority of market mechanisms of regulation of relations in FHE, Ukrainian colleagues, on the contrary, subordinate the market mechanism to government regulation of this field.

Presence of cross-cultural differences indicates that Western HE systems chose the Atlantic model as a guide, which reduces HEE activity regulation to the required minimum.

Ukrainian HE is distinguished due to HEE hierarchy, which is an integral feature of the continental model. The hierarchy is based on clauses 30 and 43 of the Law of Ukraine "About education" (hereinafter – Law 2), in which ranging according to HE education-qualification levels was performed by means of licensing and accreditation procedures [17]. Then, Provision of education-qualification levels (stage education) contained explanation of the levels content that enabled HEEs to find their position in the hierarchical educational structure according to its potential and ambitions [18]. In accordance with paragraph 7, clause 1 of Law 1, HEE functions by a license allowing performance of educational activity at certain HE levels stated in clause 5. Clause 28 contains indication to HEE types that, according to each type, govern the branch format, types of activity, HE scientific level of training. Clauses 29 and 30 contain regulation of activity of a national HEE and a research university, respectively [16]. So, during the whole period of time HEE hierarchy was a characteristic feature of Ukrainian HE.

Two previous features admit close relationship between Ukrainian HEE and Public administration bodies, which also confirms HE inclination to the continental model. First of all, this relationship demonstrates rapport between establishments and central executive bodies in the field of education and science or local authorities whose sphere of management includes higher educational establishments. Powers of these bodies are presented in clauses 12, 13 and 14 of Law 1 [16]. It should be noted that the ownership form of most powerful and authoritative HEEs a priori confirms their close relation with the state. It is assumed that both central and local bodies are to defend the interests of public, person and business in relation with HEE. So, the relation demonstrates presence (absence) of interest parity in relationship of establishments and bodies. If it is considered that all aspects of HEEs activity are to some extent controlled by a central or local body, there is no parity interest in this relationship, and it is not for the benefit of HEE. It is formally confirmed by licensing (clauses 1, 13, 24, 73, paragraphs 5, 18, part XV of Law 1) and accreditation (clauses 1, 8, 13, 18, 20, 25 of Law 1) procedures that, in their essence, authorize HEEs activity. Inseparable connection of HEEs with the central body is supported due to HE standards and standards of educational activity (part III, Law 3).

In fact, the organization of educational space of Ukrainian HE is of a unitary type characteristic of the continental model. According to this type, HE central regulation dominates over regional one, which, from the point of view of V. Vahshtein, levels territorial differences as in Holland or France [14, p. 59]. I. Pasinovych, on the contrary, considers that HE efficiency and development trends depend on the structure of regional economics as enterprises reveal demand for highly qualified personnel and results of scientific research [7, p. 13].

The continental model is based on a one-level scheme of study (five-year education program) and early students' specialization. In accordance with clause 30 of Law 2 an education-qualification level of "junior specialist" (hereinafter – "js") was introduced [17]. It was stated in the Regulation of education-qualification levels (stage education) that training "js" as lower-level specialists with HE is provided according to educational and professional training programs. The programs determine the training content stated in educational and qualification characteristics – state documents in the form of a system of production functions, typical activity problems and skills necessary for solving these problems [18]. So, students' early professional orientation typical of the continental model takes place already at "js" level.

According to paragraph 1, clause 5 of Law 1, the HE initial level provides acquisition of professionally oriented training, special skills and knowledge and also certain experience of their practical application aiming at performance of typical tasks allowed for initial positions in corresponding branch of professional activity [16]. The list of knowledge branches and specialties according to which HE getters are trained, approved in 2015, also refers to the degree of "junior bachelor" (hereinafter – "jb") corresponding to HE initial level [19]. So, this feature of continental model is still topical.

Terms "entrepreneurship" and "commerce" entered the educational lexicon. Analyzing the definitional notion "academic entrepreneurship", D. Urbano and M. Gerrero came to the conclusion as to the absence of semantics consensus. They determined entrepreneurial university parameters: organizational adaptation to changes of surroundings; management of any potential; new activity type orientation to development of entrepreneurship culture at all levels; creation of enterprises and research commercialization for the sake of economic development. Entrepreneurial university is a focus providing support for teachers and student structures aiming at creation of new intellectual, commercial and hybrid enterprises [5, p. 41-43].

M. Shattock thought that B. Clark's description of an entrepreneurial university got the status of an icon among university models in XXI century. However, use of the term "entrepreneurship" by scientists and practical workers did not cause revolution in most British universities due to cultural and administrational bans. Universities declared entrepreneurship as their mission element that controlled their affairs in the least entrepreneurial way. The author emphasizes existence of "entrepreneurial science" and states that academic and financial entrepreneurship go side by side [2, p. 51, 111, 147].

Clause 27 of Law 1 determines the legal status of HEE and states that the establishment operates on non-profit basis [16]. Hence legislation prohibits HEEs to obtain profit, which makes it impossible to use the term "entrepreneurial" in relation to their activity. This circumstance explains the attitude of Ukrainian specialists to entrepreneurship in FHE. O. Romanovskyi thoroughly characterizes features of commercial academic activity of entrepreneurial universities. The author proposes to look for ways for improving the efficiency of cooperation of Ukrainian HEE with industry and state, reveals conditions for introduction of civilized entrepreneurship in Ukrainian

HE [9]. I. Pasinovych defines entrepreneurship as a market phenomenon that in HEE research and educational activity plays the role of a factor that can significantly increase the rates of economic growth of the country. She admits that relating HEE to entrepreneurial structures of social sector and an education degree – to HEE trade mark are features of market organization of education. Appearance of innovative and entrepreneurial functions of HEEs caused nascence of an entrepreneurial university concept aiming at combination of educational mission with entrepreneurial management [7, p. 10]. It is remarkable that M. Shattock considers the state to be the first restrictive element of the use of entrepreneurial climate advantages [2, p. 146].

D. Bok understands commerce as a desire to obtain profit from teaching, research and other activities [1, p. 24-36]. I. Pasinovych determines commercialization as the first step to development of entrepreneurship in FHE. She treats commercialization as provision of educational services for payment, which is carried out by state and private HEEs [7, p. 10, 16]. However, O. Dubrovka is sure that HE is a non-commercial activity and use of marketing in HE government management is of a non-commercial character as it is based on a concept of non-commercial marketing [13, p. 5, 7, 10, 13].

It should be stated that while Western specialists regard successful commercial activity of universities as an example to be followed, attitude of Ukrainian specialists to commerce in FHE is controversial. In the West the notion "entrepreneurial university" became a common noun that embodies the best qualities of modern HEEs. In its turn, attitude of Ukrainian specialists can be explained by absence of significant cooperation for succession as every particular case of cooperation of a HEE with business is exceptional. Absence of relation between HEEs and business is an inseparable feature of the continental model; this feature is also inherent in Ukrainian HE.

Therefore, the continental model features are intrinsic in Ukrainian HE. They are inherited from the education system of the USSR according to which specialists with fundamental knowledge were trained during five or six years by government order. As a rule, HE was obtained once in a life. Market realities of the recent decades proved that knowledge obtained in HEE is not sufficient for the contemporary graduate. Fundamental knowledge often does not meet the requirements of employers; so many specialists have to master new specialties.

Under the market conditions Ukrainian HE chose orientation to the Atlantic model whose ardent advocates include universities in the USA, Canada, Great Britain, Ireland. Historically, the model is built on two stages: "baccalaureate+magistracy". The stage education was officially mentioned for the first time in clause 30 of Law 2 where, besides education-qualification level "bachelor" (hereinafter – "b") and "master" (hereinafter – "m"), also "junior specialist" and "specialist" (hereinafter – "s") are present [17]. It should be mentioned that levels "js" and "s" remained from education in the USSR. According to clause 5 of Law 3, providing HE to specialists is performed at five levels. At the first level the educational degree "b" is attained, at the second level – "m". I.e., according to reformation, an educational degree is attained exclusively at the first and the second levels as at other levels other degrees are obtained, for example, at the initial level an educational-professional degree is achieved, at the third level – an educational and simultaneously the first scientific degree, at the scientific level – a scientific degree [16]. So, Law 1brought educational degrees into conformity with the standard of liberal model. This is a model of late professional differentiation when the student in baccalaureate determines the line of study and obtains basic knowledge and skills and in magistracy, if necessary, he/she majors in the field that will be useful for future professional activity.

Institutional and financial autonomy of HEEs is a specific feature of the Atlantic model. Terms "HEE autonomy", "HEE self-government", "academic freedom" have been mottos of Ukrainian HE reformation in the recent two decades. The definition of the term "higher educational establishment autonomy" is given in paragraph 1, clause 1, Law 1. Development of HEE autonomy and academic freedom of participants of educational process is one of the ways of generation and realization of the government policy in FHE according to paragraph 3, clause 2 [16]. I. Pasinovych relates the high level of HEE autonomy, their self-government system and orientation to non-government financing to the features of market organization of education. The author explains the growth of the state functions as to finding the best balance between HEE autonomy and state influence in FHE by appearance of private HEEs and "non-university" sector of HE [7, p. 10].

Real autonomy implies existence of HEE self-government, which is characteristic of the Atlantic model. This is possible on condition of minimum government control over HEE activity. As mentioned above, the government control over FHE is determined by legislation. According to clause 77, Law 1, the government control implies the supervision of the central executive body over the HEE as to its observance of FHE legislation, which provides realization of the government policy [16]. I.e. there is a direct control of the state over FHE activity, which excludes the possibility of active self-government.

As stated above, Ukrainian HEE did not establish cooperation with business environment. However, V. Vahshtein refutes the idea that in the countries which adopted this model non-government commercial universities dominate. Such situation is characteristic of the USA and Canada and not typical of Great Britain and Ireland and also of other Atlantic systems [14, p. 57]. In the opinion of I. Pasinovych, appearance of private HEEs as an inseparable element of FHE market and generation of a "non-university" sector promotes diversification of provided forms of educational services [7, p. 12]. In 1995/1996 academic year there were 111 private HEEs, which made 10.70% of their total number. The share of students in these HEEs made 4.61% of the total number. Taking into consideration the fact that the possibility of creation of private HEEs appeared only in 1991, during four years the private sector was generated rapidly. During the following decade the number of private HEEs doubled and in 2005/2006 academic year there were 202

establishments, which made 21.24% of the total number. The share of students in private HEEs tripled (14.73% of the total number). In 2013/2014 academic year their number decreased to 167 establishments, but the share remained almost at the same level (20.79%). The share of students reduced to 9.31 % [20, p. 7, 9, 10]. Thus, the Private sector did not dominate numerically in FHE, but qualitatively it demonstrated the wish and possibility to meet the demand. According to this feature Ukrainian HE would correspond to the continental model if not for one aspect.

It concerns the contingent of students who study at their own expense. In 2008/2009 academic year the share of students who studied at the expense of the government budget made 35.3% and at the expense of natural persons – 60.8%. In 2013/2014 academic year the share of "budget" students increased to 42.6% and the share of contract students reduced to 52.3% [20, p.13; 21, p.13]. Five years later the dominating source of financing considerably weakened its positions, but its leadership is obvious. The share of contract students is much higher than the share of students of private HEEs (9.31%), which certifies significant amount of HES realization by state HEEs. As the continental model, as a rule, does not imply use of other than government sources of financing, it testifies to inclination of Ukrainian HE to the Atlantic model.

A typical feature of the Atlantic model consists in the presence of specialized mediation agencies with administrative functions at HES market. So, according to paragraph 1, clause 12 of Law 1, management in FHE is performed by self-government bodies within the limits of their powers and the National Agency for provision of HE quality (hereinafter – National Agency). The state assigned the mission of providing education quality to the National Agency. According to clause 23, the National Agency, in its turn, accredits independent non-government establishments that assess and provide quality of higher education [16]. I. Pasinovych insists on generation of market infrastructure as not only HEEs and consumers but also partner companies and intermediaries are the subjects. Infrastructure means the totality of institutions providing the conditions for interaction of the subjects with surroundings [7, p. 11]. H. Goldstein and D. Drucker consider that understanding of knowledge infrastructure emerged from the endogenous theory of growth as a component of a bigger regional agglomeration of economic concept. On the regional scale the knowledge infrastructure, along with the knowledge system, worked out by state and private establishments, contains innovation and educational potential of companies, workers and a network of their relations [6, p. 23]. Thus, this feature of Ukrainian HE is on the stage of generation.

Taking the above said into account, Table 1 contains information about presence of features of the continental or Atlantic model in Ukrainian HE. As HE in Ukraine is being reformed, the feature of "presence" has three levels: = – complete presence, ≈ – partial conformity, ≠ – complete unconformity.

The logic of the Atlantic model of HE consists in economic expediency and of the continental model – in government order and the function of reproduction of social structure. In XXI century this difference is leveled as the liberal model goes through "governmentalizing" and the continental one – through liberalization. This tendency explains construction of binary typology of national FHE, in particular, in Ukraine. In its essence it is an attempt to relate to national differences of educational models, find their inviolable cultural-historical grounds and provide them with determinative force. Moreover, national FHE reveals a tendency to continuous institutional transformation; it changes more rapidly than the next binary typology has time to distribute. It is only expedient to systemize the vectors of their variation.

Table 1. Presence of features of the continental or Atlantic model in Ukrainian HE

Continental model of higher education		**Atlantic model of higher education**	
Feature	*Presence in Ukraine*	*Feature*	*Presence in Ukraine*
Direct government regulation	=	Indirect government control over the activity of HEEs	≠
HEEs hierarchy	=	Presence of specialized mediator agencies	≈
Close relationship of HEE with authorities	=	Institutional financing autonomy of HEEs	≈
Early professional specialization of students	=	Late professional specialization of students	≠
One-level scheme of study	≠	Two-level scheme of study	≈
Absence of cooperation of HEE and business	≈	Close cooperation of HEE and business and a considerable level of paid HES	≈

CONCLUSIONS

Thus, the above said makes it possible to come to conclusions.

1. Government regulation indicates that the society assisted by the state bodies and social institutes tried to prevent the saturnalia of entrepreneurship in FHE. Great efforts were made to create conditions for civilized business in this field. Transformation of relations at the level of principles in this field certainly causes changes in the society on the whole.

2. The Atlantic model was taken as a development vector, but, due to inertia, Ukrainian HE cannot achieve complete conformity.

3. Judging by the results of reformation, withdrawal from the continental model will take a lot of time. Refusal from national traditions and, undoubtedly, positive past will be followed by both criticism of the reforms and partial refusal from them.

Introduction of new market methods, ways and forms into HEE activity will inevitably cause consequences. Western scientists attribute more importance not to market relationship but to results of experiments with

original forms and methods. Consequences may reveal both at once and after a considerable period of time; they may be of both positive and negative character. It is the study of them that the further research is oriented to.

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Application of the method of the nonparametric identification of nonlinear dynamic control objects for the crushed vulcanization modification

O. Fursa, A. Gyrenko, A. Cheremysinova, A. Sheikus

Ukrainian State University of Chemical Technology; e-mail:yaroslav_dfz@mail.ru

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Abstract. Solving a problem of building the automatic control system of the industrial rubber article technological process by means of modeling software is one of the essential parts of providing the technological effectiveness. The work concerns the problem of application of the method of the nonparametric identification of a nonlinear dynamic control object for the process of modification of crushed vulcanized rubber. This process is an explicit nonlinear and nonstationary system of control parameters. The application of this method allows to obtain reliable information on an object without difficult computation, and the reliability of the method is corroborated graphically and with the computation. Depending on the degree of complexity of an object this method can be deterministic or probabilistic, can describe only time development, only spatial development or time-spatial development of an object. The influence of the process type on the identification results was analyzed in the work. Therefore, the task of increasing the quickness of information selection about the object is still a topical problem for the non-parametric identification. Conclusions about a possibility of activation of the identification procedure were made. The elaborated algorithm allows to apply it for other technological processes with self-adjusting systems when the condition of quasi-stationarity is fulfilled.

Key words: control object, identification, adaptive control system, crushed vulcanized rubber, modification.

INTRODUCTION

One of the important scientific problems of natural science is solving the problem of predicting the behaviour of an object under study in time and space on the basis of specific knowledge of its initial state. This problem consists in finding a law that allows to predict the object motion at any time $t > t_0$ on the basis of the existing information about the object at the initial time t_0 at the point x_0. Depending on the degree of complexity of an object this law can be deterministic or probabilistic, can describe only time development, only spatial development or time-spatial development of an object.

The subject of our analysis is a specific object of a dynamic system in mathematical conception of the term.

Crushing equipment for obtaining crushed vulcanizate is evident non-linear and non-stationary control object which characteristics and parameters depend on the properties of the processed recyclable materials and vary in a wide range.

A research of real systems consists in the study of mathematical models, which improvement and development are determined by the comparative analysis of experimental and theoretical results. In this regard, under the dynamic system we will imply its mathematical model.

In mathematics, a dynamical system is a set of relationships among two or more measurable quantities, where there are fixed ruledescribes as the quantities which evolve over time in response to their own values. Examples include the mathematical models that describe the swinging of a clock pendulum, the flowing of water in a pipe, and the number of fish in a lake in springtime. At any given time a dynamical system has a state which had been given by a set of real numbers (a vector) that can be represented by a point of an appropriate state space (a geometric manifold).

The evolution rule of the dynamical system is a function that describes that future states will follow from the current state. Often the function is deterministic; in other words, only one the current state has an influence on the one future state for a given time interval;[1,2] However, some systems are stochastic, random events have also affect on the evolution of the state variables.

The concept of a dynamical system has its origins in Newtonian mechanics. There, as in other natural sciences and engineering disciplines, the evolution rule of dynamical systems is an implicit relation that gives the state of the system for only a short time into the future. (The relation is either a differential equation, difference equation or other time scale.) To determine the state for all future times requires iterating the relation many times – each advancing time a small step. The iteration procedure is referred to as solving the system or integrating the system. If the system can be solved, given an initial point it is possible to determine all its future positions, a collection of points known as a trajectory or orbit.

Before the advent of computers, finding an orbit required sophisticated mathematical techniques and could be accomplished only for a small class of dynamical systems. Numerical methods implemented on electronic

computing machines have simplified the task of determining the orbits of a dynamical system [3]. For simple dynamical systems, knowing the trajectory is often sufficient, but most dynamical systems are too complicated to be understood in terms of individual trajectories. The difficulties arise because:

• The systems studied may only be known approximately – the parameters of the system may not be known precisely or terms may be missing from the equations. The approximations used bring into question the validity or relevance of numerical solutions. To address these questions several notions of stability have been introduced in the study of dynamical systems, such as Lyapunov stability or structural stability. The stability of the dynamical system implies that there is a class of models or initial conditions for which the trajectories would be equivalent.

• The type of trajectory may be more important than one particular trajectory. Some trajectories may be periodic, whereas others may wander through many different states of the system. Applications often require enumerating these classes or maintaining the system within one class. Classifying all possible trajectories has led to the qualitative study of dynamical systems, that is, properties that do not change under coordinate changes. Linear dynamical systems and systems that have two numbers describing a state are examples of dynamical systems where the possible classes of orbits are understood.

• The behavior of trajectories as a function of a parameter may be what is needed for an application. As a parameter is varied, the dynamical systems may havebifurcation points where the qualitative behavior of the dynamical system changes. For example, it may go from having only periodic motions to apparently erratic behavior, as in the transition to turbulence of a fluid.

• The trajectories of the system may appear erratic, as if random. In these cases it may be necessary to compute averages using one very long trajectory or many different trajectories. The averages are well defined for ergodic systems and a more detailed understanding has been worked out for hyperbolic systems. Understanding the probabilistic aspects of dynamical systems has helped establish the foundations of statistical mechanics and of chaos.

THE ANALYSIS OF RESEARCHES AND PUBLICATIONS

An important source of saving of input materials in rubber production is the use of waste tyres and waste products of different rubber goods. Technical properties of the materials of the tyres and other elastomeric products are preserved to the utmost when processed by shredding-recycling method. Products of crushing are then re-used in the production process. The structure and properties of rubber crumb particles strongly depend on the ways of crushing (processing) of worn tyres and crushing of tyre rubber. The following energy treatments are used:

- cutting;
- shearing;
- electromagnetic and ultrasonic waves;
- electrical discharge;
- laser beam;
- shock action [4; 5].

Crushed vulcanizate can be used effectively when reclaiming it or modifying surface with active materials [6-9].

In these processes the destruction of the vulcanization network occurs as a result of increasing the rate and uniformity of penetration of a destructurizing agent into rubber crumb particles. Polymer degradation is a change in the properties – tensile strength, colour, shape, etc. – of a polymer or polymer-based product under the influence of one or more environmental factors such as heat, light or chemicals such as acids, alkalis and some salts. These changes are usually undesirable, such as cracking and chemical disintegration of products or, more rarely, desirable, as in biodegradation, or deliberately lowering the molecular weight of a polymer for recycling. The changes in properties are often termed "aging"[4].

In a finished product such a change is to be prevented or delayed. Degradation can be useful for recycling/reusing the polymer waste to prevent or reduce environmental pollution. Degradation can also be induced deliberately to assist structure determination.

Polymeric molecules are very large (on the molecular scale), and their unique and useful properties are mainly a result of their size. Any loss in chain length lowers tensile strength and is a primary cause of premature cracking [10, 11].

The specific character of mechanical failure of worn tyres is that at either low or normal or not very high temperatures the crushing process leads to the formation of rubber particles with a smooth surface, which looks like broken glass [12-16]. Such particles have a low adhesion to raw rubber and to the majority of polymeric thermoplasts. They are poorly soluble in bitumen and poorly sorb oil products. To modify their surface and to make it less smooth, rubber particles expose to various factors that promote devulcanization of the surface layer: flash heating of the particles with superheated steam, heating with a laser, treating with gamma rays with the following grafting of different monomers to the surface, sulfur deposition on the surface, ets. At present the search and the development of new ways for rubber crumbs modification are carried out in the areas:

1.chemical modification and softening the surface of rubber particles;

2.physicochemical crushing by breaking polymeric bonds (similarly to the regeneration);

3.physicochemical treatment with the aim of sulfure bonds breakage.

Rubber crumbs with particles size up to 5 mm obtained on roll crushers and rotor crushers were selected for the study [17-18].

Operating effectiveness of the system is determined by the quickness and reliability of selection of the information about the object which is necessary for object identification. Building a self-adjusting system is possible if it is assumed that its structure is invariable and known a priori. Thus, the identification problem consists in finding

the unknown parameters [19]. A much more common approach is therefore to start from measurements of the behavior of the system and the external influences (inputs to the system) and try to determine a mathematical relation between them without going into the details of what is actually happening inside the system. This approach is called system identification. For the selection of the necessary information a long-time interval is required, which may lead to a quasi- stationarity breakdown. Therefore, the task of increasing the quickness of information selection about the object is still a topical problem for the non-parametric identification [20; 21].

Adaptive system (self-adjusting system) automatically changes the algorithms of its operation and its structure in order to maintain or achieve an optimal state as external conditions change [22; 23].

Under the dynamic system is implied any object or process for which clearly defined the concept of the state as a combination of certain variables at a point of time and determined the function that describes the time change of the initial state. This function allows to predict a state of a dynamic system on the basis of an initial state, and it is called the law of evolution. Dynamic systems are mechanical, physical, chemical and biological objects, computation processes and information conversion processes which are performed according to the specific algorithms. Descriptions of dynamic systems for defining the law of evolution are also diverse: with the help of differential equations, discrete mapping, graph theory, the theory of Markov chains, etc. The choice of the way of describing sets a specific form of a mathematical model of a dynamic system [24]. A mathematical model is a description of a system using mathematical concepts and language. The process of developing a mathematical model is termed mathematical modeling. A mathematical model of a dynamic system is considered to be set if system coordinates are entered and they uniquely determine the system state, and the law of evolution is defined. Depending on the degree of approximation various mathematical models can be assigned to the same system. In many cases, the quality of a scientific field depends on how well the mathematical models developed on the theoretical side agree with results of repeatable experiments. Lack of agreement between theoretical mathematical models and experimental measurements often leads to important advances as better theories are developed.

Dynamic systems, simulated by a finite number of ordinary differential equations, are called single-site or point systems. They are described with a finite-dimensional phase space and are characterized by a finite number of degrees of freedom. The same system in different conditions can be regarded either as point or as distributed system. Mathematical models of distributed systems are partial differential equations, integral equations or ordinary equations with lagging argument [25,26]. A number of degrees of freedom of a distributed system is infinite, and infinite data set is required to determine its state. On the basis of energy characteristic the dynamic systems are divided into conservative and nonconservative. Conservative systems are characterized by the energy content which is invariable in time. In mechanics they are called Hamiltonian. For conservative systems with n degrees of freedom the Hamiltonian of the system $H(p,q)$ is set, where q_i are the generalized coordinates, p_i are generalized pulses of the system, $i = 1, 2,\_,n$. The Hamiltonian completely characterizes the dynamic nature of the system and in terms of physics it in most cases represents the total energy of the system. The time evolution of conservative systems is described by the Hamiltonian mechanics [27-29].

Dynamic systems with time-varying energy content are called nonconservative. Systems in which energy decreases in time due to friction or dissipation are called dissipative. Accordingly, systems in which energy increases in time are called negative friction systems or negative dissipation. Such systems can be regarded as dissipative when the time direction is changed into the opposite [30, 31].

OBJECTIVES

The aim of the work was to establish the possibility of the application of the method of nonparametric identification for the control of the nonlinear dynamic system of parameters for the process of modification of crushed vulcanizate.

THE MAIN RESULTS OF THE RESEARCH

To solve the problem of building automatic control system of the process of modification of crushed vulcanizate we used the mathematical model [32] which describes nonstationary nonlinear system of the process parameters. The system includes a tandem of nonlinear inertialess and linear dynamic elements. The model is shown in Fig.1.

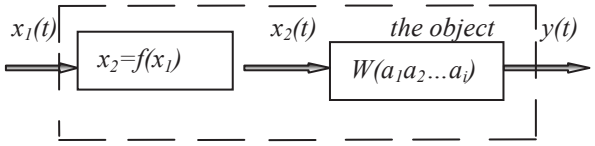

Fig. 1. Block diagram of the process of modification of crushed vulcanizate

The structure of the operator $W(a_1a_2...a_i)$ is known. From the measured input parameters $x_1(t)$ and output parameters $y(t)$ of the process within a time interval $0 \div T$ it is necessary to determine the steady-state characteristic of the object $x_2=f(x_1)$ and parameters $a_1a_2...a_i$ of the operator W.

When the supposition about the quasistationarity within the interval is made, the same values of x_1 correspond to the same values of x_2. Characteristic x_2 cannot be measured directly, however, it can be calculated from the $y(t)$ by the inverse transformation which looks like:

$$x_2(t)= W^{-1}[y(t)] \quad (1)$$

Parameters $a_1a_2...a_i$ of the linear operator W are unknown and identification problem consists in the finding the values of $a_1a_2...a_i$ to meet the supposition in the best way, and the criterion is the within-group variance.

Realizable algorithm:

1. It was supposed that the measured parameters $x_1(t)$ within the interval $0 \div T$ have a variability in the operating range from x_{1min} *to* x_{1max}. The range was divided into n small intervals with an increment:

$$h = (x_{1max} - x_{1min})/n.$$

It was assume that x_{1j} was the middle of the j^{th} interval, where j was an integer series from *1* to n.

2. For the set values of parameters $a_1a_2...a_i$ the inverse transformation was performed which looks like:

$$x_2(t) = W^{-1}(a_1a_2...a_i)*[y(t)] \quad (2)$$

3. The characteristic $x_2(t)$ within the time interval $0 \div T$ was written in the form of discrete equidistant values x_{2i} where i was an integer series from *1* to k with a time sampling interval:

$$\Delta t = T/k.$$

4. The array x_{2i}, where i was an integer series from *1 to k*, was divided into n groups of appropriate intervals x_{1j}, where j was an integer series from *1 to n*.

5. For each j^{th} group the group average x_{2j} and the group variance Dj were computed.

6. For the entire array x_{2i} the within-group variance Dv was computed.

7. The computations for items 2÷6 were iterated for the new values of parameters $a_1a_2...a_i$ until for a certain set of values the minimum value of within-group variance is found.

That is this algorithm solves the problem:

$$Dv \rightarrow min_{a1...am} \quad (3)$$

The values of parameters $a_1a_2...a_i$ provides the minimum of within-group variance and are the result of the identification.

It was advisable to analyze the influence of the $x_1(t)$ type on the results of the identification. The identification procedure can be activated when changing the input parameters $x_1(t)$ within the entire operating range (Fig. 2).

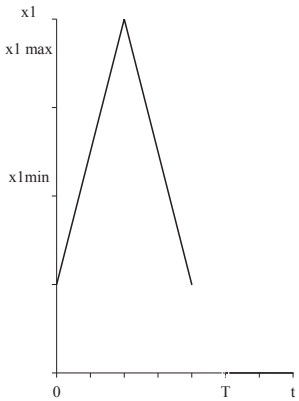

Fig. 2. The transient process $x_1(t)$ in operating range.

It can significantly reduce the time $0 \div T$ required for the selection of the information about the object when the input effect had been preset as in Fig. 3.

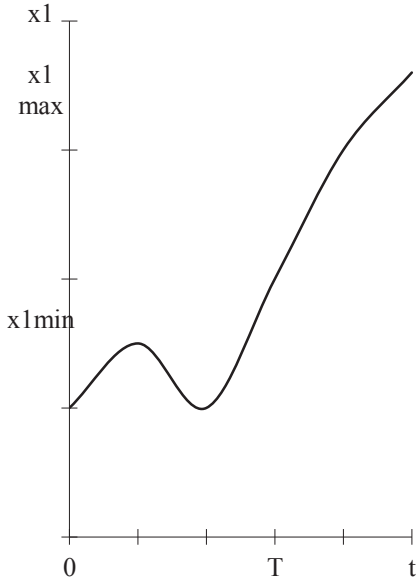

Fig. 3. The transient process $x_1(t)$ with preset input effect

The above process can be illustrated according to the flow-circuit control method (Fig. 4).

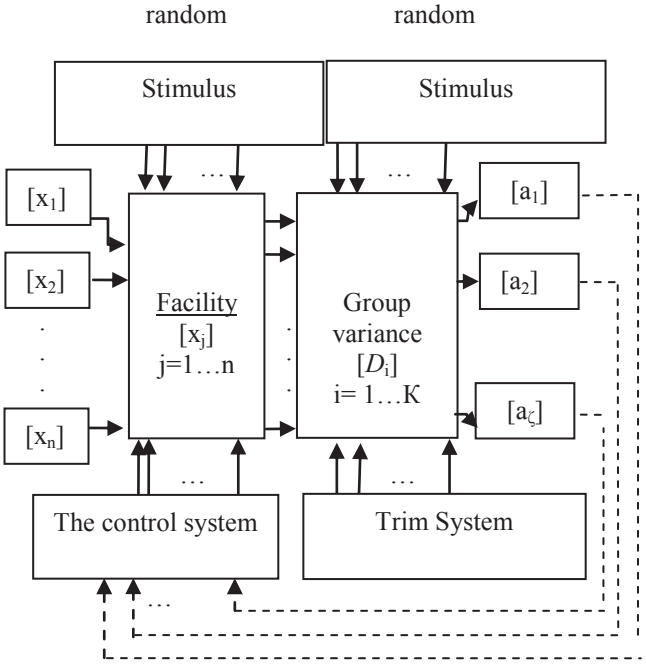

Fig. 4. A block diagram of the control method

where:

$[x_1],\ldots,[x_n]$ – matrix of the component input parameters,

$[a_j], j=1,\ldots,i$ – the reaction matrix of the object to the input component,

$[x_i], i = 1,\ldots,k$ – matrix parameters,

$[a_\zeta]$, $\zeta = 1, \ldots, l$ – output parameters of matrix system.

The calculations which were carried out in this work can be represented graphically (Fig. 5).

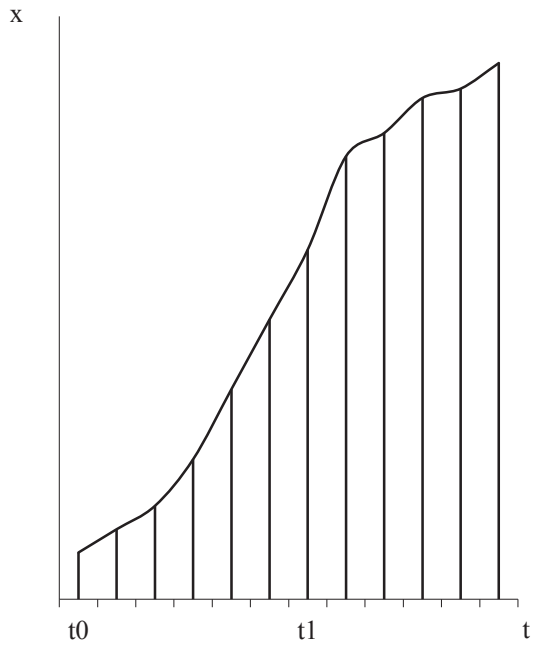

Fig. 5. Diagram of experimental dependence $x_1(t)$

CONCLUSIONS

1. Given method of nonparametric identification of nonlinear nonstationary objects allows to reduce the time of selection of the information about the object, and it is a decisive factor of the efficient operation of adaptive control systems.

2. It was solved the problem:

$$Dv \rightarrow min_{a1 \ldots am}$$

It provides a minimum intra-dispersion.

3. The effect of the type of $x_1(t)$ on the results of identification was analyzed.

4. The activation of the identification procedure over the entire operating range was shown.

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Data-based method for the determination of temperature dependence of heat capacity of highly dispersed powders

A. Karnina, A.Gyrenko, A. Klymenko, O. Mysov

Ukrainian State University of Chemical Technology, e-mail: alena.karnina@yandex.ru

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Abstract. Accuracy of engineering and economic calculations in different areas requires the use of accurate and prompt values of heat capacity for new or modified materials. A number of existing methods have an error in measuring the heat capacity of powder materials, and use non-standard devices and electric heaters which are not produced industrially. This work is aimed at developing the method for determining the heat capacity of the powder, accuracy evaluation of this method and mathematical processing of experimental data to determine the temperature dependence of the molar heat capacity. To solve the problem the method based on the DTA technique was developed. The measuring apparatus for determining the temperature dependence of the heat capacity includes two standard cups for DTA analysis with investigated material and MgO, heat-variable resistor of film type Pt100, multichannel recorder. The apparatus is placed in a drying oven. From the theory of heat transfer and the assumption about steady-flow heat transfer the equation for molar heat capacity was obtained. The method requires the measuring of temperature of the investigated material and MgO during the linear heat of the drying oven as well as air temperature in the oven. Empirical values of heat capacity of standard substances calculated by the equation for each temperature were compared with the values from reference data. The uncertainty of finding the heat capacity did not exceed 0,5%.

Key words: highly dispersed powder, heat capacity, equations, experimental measurement, uncertainty of measurements.

INTRODUCTION

Heat capacity is an important property of highly dispersed powder materials. Highly dispersed powders are systems that consist of solid particles with developed surface which are separated by gas phase. They are oxides, ceramic materials, various powders, soils, and so forth. The values of heat capacity of materials are used in the modelling of heat processes, thermodynamic, engineering and techno-economic calculations in areas such as electronics, construction, chemical and food technology. The value of heat capacity of materials is effected by a chemical composition, a presence of impurities, moisture and material structure. That is, even little changes in these parameters lead to changes in the heat capacity, and accordingly, the heat properties of the material. Accuracy of engineering and economic calculations requires the use of more accurate and prompt values of heat capacity for new or modified materials. Thus, the actual problem is measuring the exact heat capacity of a powder preferably with the use of common measuring instruments and easily programmable algorithm of processing of the experimental data. Moreover, the heat capacity considerably dependents on the temperature of the substance. For most calculations it is desirable and necessary to know the temperature dependence of heat capacity, and finding this dependence is undoubtedly more complex task compared to point or average values.

THE ANALYSIS OF RESEARCHES AND PUBLICATIONS

The problem of finding the heat capacity arose before the authors of this work within the development of technology for obtaining new highly dispersed materials based on vanadium, with unique properties for use in electronics as data carriers, switches and supercapacitors, namely: nanosized vanadium (IV) oxide [1] and vanadium (III) nitride [3]. These materials are proposed to obtain by the appropriate heat treatment of the ammonium salt of the polivanadium acid – ammonium tetravanadate (IV) $(NH_4)_2V_4O_9$ (hereinafter ATV).

A significant shortage and limited experimental data on the thermodynamic properties of many substances, including ATV, raises the need to develop and use a variety of methods, most empirical, for their calculation and estimation [3-5].

A number of existing calculation methods for determining the heat capacity – Debye equation, Kopp-Neumann rule [6] – in principle does not allow to find the temperature dependence of heat capacity [7]. Known experimental methods [8-12] have a number of drawbacks, the main of which is the complexity of the measuring apparatus design, which includes a large number of elements, required thermostating and heat protection. This all makes error in measuring the heat capacity of solid bulk materials, effecting the components of heat balance. Many methods use non-standard devices and electric heaters which are not produced industrially.

OBJECTIVES

The aim of this work in the first place was to develop the method for determining the heat capacity of the powder, based on differential heat analysis, accuracy

evaluation of this method and mathematical processing of experimental data to determine the temperature dependence of the molar heat capacity. As a result, it is necessary to obtain empirical function of temperature dependence of ATV heat capacity.

THE MAIN RESULTS OF THE RESEARCH

For the study ATV samples were synthesized accrding to the sol-gel method as described in [13, 14]. The object of research contained 99 mol% of vanadium (V) and 1 mol% of vanadium (IV), which was determined by the method [15].

To solve the problem of determining the temperature dependence of ATV heat capacity, the method based on the DTA technique was developed (Fig. 1).

Two identical thin quartz cups, standard for DTA method, were filled with the investigated material and MgO (comparison material) that have been pre-dried and brought to a constant weight. At this stage the assumption on absolute equality of mass and geometry of quartz cups was made. They were placed in a drying oven as in Fig. 1. The linear heating was implemented at a rate of 2,5 ± 0,2 degrees/minute. The temperatures of powders and air in the oven were measured with the multichannel recorder.

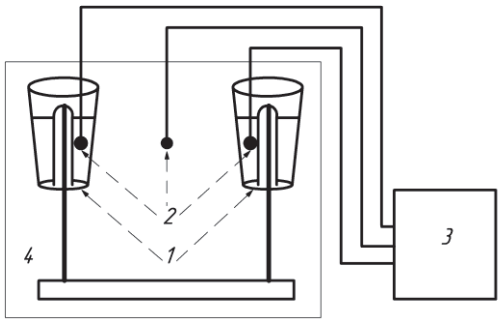

Fig. 1. Structure of the measuring apparatus for determining the temperature dependence of the heat capacity: 1 – standard cups for DTA analysis with investigated powder and MgO; 2 – heat-variable resistor of film type Pt100 with measurement error ± 0,15^{0}C; 3 –multichannel recorder RMT69Ex; 4 – drying oven.

In the implemented experiment the heat transfer occurred by convection [16]: hot heat-transfer agent (air) → cup wall → cold heat-transfer agent (powders).

We accept the assumption that the heat transfer process is steady-flow. In this case, the condition (1) fulfils:

$$Q = Q_1 = Q_2 = Q_3 \quad (1)$$

where: Q_1 – heat given by the air outside the cup wall, J; Q_2 – heat transferred from the outside of the wall to the inside of the cup wall, J; Q_3 –heat transferred from the inside wall of the cup to the powder, J.

That is the amount of the heat given by the hot heat-transfer agent (air) equals to the amount of heat adopted by the cold heat-transfer agent (powders of the investigated powder and MgO). From the theory of heat transfer the heat which is transferred from the hot to the cold heat-transfer agent is calculated according to (2, 3):

$$Q_1^P = kS(T_i^A - T_i^P)\,\tau, \quad (2)$$
$$Q_2^{MgO} = kS(T_i^A - T_i^{MgO})\,\tau, \quad (3)$$

where: Q_1^P, Q_2^{MgO} – the amount of heat given by air to the investigated powder and MgO respectively, J; T_i^A, T_i^P, T_i^{MgO}– values of temperature of air, investigated powder and MgO in the ith point of time, K; τ – time, sec; k – coefficient of proportionality, which is called the heat-transfer coefficient, S – area of heat transfer (assumed to be constant).

On the other hand, the amount of heat taken by the cold heat-transfer agent depends on its heat capacity according to (4, 5):

$$Q_3^P = C_p^P \nu^P (T_i^P - T_0^P), \quad (4)$$
$$Q_3^{MgO} = C_p^{MgO} \nu^{MgO} (T_i^{MgO} - T_0^{MgO}), \quad (5)$$

where: Q_3^P, Q_3^{MgO} – heat adopted by the investigated powder and MgO, respectively, J; C_p^P , C_p^{MgO} – molar heat capacities of the investigated powder and MgO respectively, which depend on the temperature, J/(mol·K); $(T_i^P - T_0^P)$, $(T_i^{MgO} - T_0^{MgO})$ – the difference between the values of temperature at ith point of time and initial temperature of the investigated powder and MgO, respectively, K; ν^P , ν^{MgO} – amount of heated investigated powder and MgO, respectively, mole.

In the steady-state condition on the basis of (1) the system of equations can be obtained:

$$\begin{cases} Q_1^P = Q_3^P \\ Q_1^{MgO} = Q_3^{MgO} \end{cases}. \quad (6)$$

Taking into account the equations (2 – 5), after dividing the first equation of the (6) by the second one and writing expression as the equation of the heat capacity C_p^P, we have (7):

$$C_P^P = \frac{C_P^{MgO} \nu^{MgO} \left(T_i^A - T_0^P\right)\left(T_i^{MgO} - T_0^{MgO}\right)}{\nu^P \left(T_i^A - T_0^{MgO}\right)\left(T_i^P - T_0^P\right)}. \quad (7)$$

The equation (7) allows to find the value of the heat capacity at ith temperature. Experimental values of heat capacity at different temperatures are usually presented in the form of an equation (8):

$$C_p = a_0 + a_1 T + \ldots + a_n T^n, \quad (8)$$

where: $a_0 \ldots a_n$ – empirical coefficients.

To find the function of ATV heat capacity on temperature the empirical values were approximated by polynomials (Fig. 2).

In regression analysis [17, 18, 19] of the dependence of the ATV heat capacity on the temperature, the following polynomial models with corresponding coefficients of determination R^2 were obtained:

$$C_P(T) = 218{,}27 + 0{,}26\,T;\ R^2 = 0{,}9858, \quad (9)$$
$$C_P(T) = 213{,}73 + 0{,}29\,T - 0{,}00004\,T^2;\ R^2 = 0{,}9858. \quad (10)$$

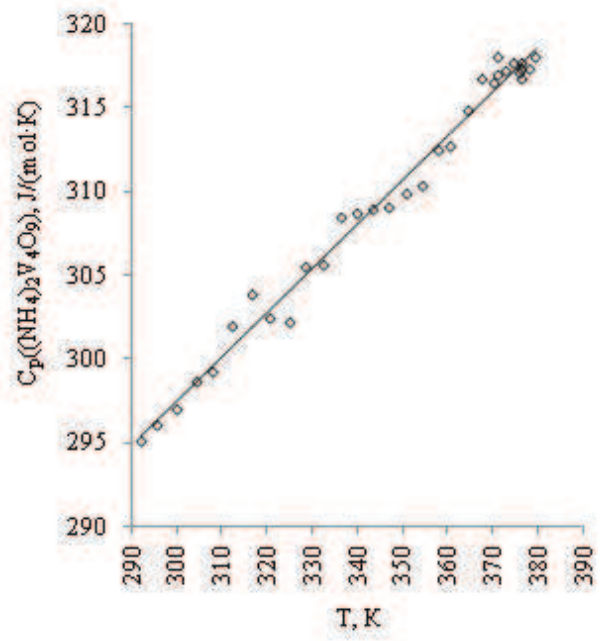

Fig. 2. Dependence of molar heat capacity of ATV on temperature: ◇ – empirical, —— – regression model

The equations accurately describe the dependence within the experimental interval 15÷110^{0}C. In the studied temperature region it is reasonable to use equation (9) in thermodynamic calculations. Irreversible chemical transformations of ATV occur at the higher temperatures.

ESTIMATION OF THE METHOD ERROR

In order to prove the acceptability of using this method of studying the temperature dependence of heat capacity, type B evaluation of instrumental measurement uncertainty and type A evaluation of measurement uncertainty were carried out [20-23].

To calculate the characteristics of instrumental measurement error of the measuring channel, which consists of a thermoelement Pt100 and a multichannel recorder PMT 69, it was assumed that all components of the error are uncorrelated, i.e. the total measurement error of the measuring channel can be found as the geometrical sum of errors or if root-mean-square errors are normalized:

$$\sigma^2[\Delta_\Sigma] = \sum\sigma^2[\Delta_i], \qquad (11)$$

where: $\sigma[\Delta_\Sigma]$ – root-mean-square error of the total instrumental erroe; $\sigma[\Delta_i]$ – root-mean-square errors of the error components.

The ambient temperature in the laboratory was 20 ± 5 ºC, i.e. the normalized additional error due to the 10 ºC change of the ambient temperature should be divided by two. Since for the used instruments root-mean-square errors were not normalized, the same distribution law for each component of the error was assumed. The equation (11) can be represented as:

$$\gamma_\Sigma = \sqrt{\gamma^2 + \left(\frac{\gamma_T}{2}\right)^2 + \gamma_U{}^2 + \gamma_M{}^2 + \gamma_{из1}{}^2 + \gamma_{из2}{}^2 + \left(\frac{\gamma_B}{2}\right)^2}$$

$$\gamma_\Sigma = 0{,}11127\ \%\,, \qquad (12)$$

where: normalized maximum permissible measurement errors of the used instruments are:

γ – basic error;

γ_T – additional error due to changes in ambient temperature;

γ_U – additional error due to the changes in voltage; γ_M – additional error due to the changes in magnetic fields; $\gamma_{из1}$, $\gamma_{из2}$ – additional errors due to the influence of longitudinal and transverse voltage noise of DC or AC; γ_B – variation.

Taking into account the instrument measurement range -50÷200 ºC (N = 250), the absolute error or the channel:

$$\Delta_\Sigma = 0{,}11127\% \cdot 250\ ^\circ\text{C} / 100\% = 0{,}28\ ^\circ\text{C}. \qquad (13)$$

In table 1 metrological performance of all measuring instruments are given.

Then the theoretical evaluation of the error of the indirect measurement of heat capacity was carried out.

In the equation (7) the experimentally measured values are temperatures T_i^A, T_i^P, T_i^{MgO} and weights of the investigated powder and magnesium oxide MgO.

Table 1. Metrological performance of measurement instruments

Measurement instruments	Normalized basic error Δ/γ	Normalized additional error Δ/γ	Normalized variation γ, %	Total calculated error of the measurement channel, Δ_T, ºC
Pt100	Δ = ± 0,15 ºC	–	–	Δ_T= 0,28 ˚C
Channel Pt100–PMT 69	γ = ± 0,1 % (range −50 … +200 ^{0}C)	$\gamma_T = 0{,}05\%$ $\gamma_U = 0{,}02\%$ $\gamma_M = 0{,}02\%$ $\gamma_{из1} = 0{,}02\%$ $\gamma_{из2} = 0{,}02\%$	$\gamma_B = 0{,}025\%$	
Analytic balance	Δ_m = ± 0,1 mg	–	–	

To evaluate the error the weights have to be explicit:

$$\nu = \frac{m}{M}, \quad (14)$$

where: m – weight; M – molar mass, g/mole.

Substituting υ in (7) with (14) the equation for heat capacity looks like:

$$C_P^{\,P} = \frac{C_P^{\,MgO} m^{MgO} M^{P}\left(T_i^{\,A} - T_0^{\,P}\right)\left(T_i^{\,MgO} - T_0^{\,MgO}\right)}{M^{MgO} m^{P}\left(T_i^{\,A} - T_0^{\,MgO}\right)\left(T_i^{\,P} - T_0^{\,P}\right)} \quad (15)$$

To calculate the uncertainty of the indirect measurements with the use of the equation (15) according to the calculation procedure [24-25] it is necessary to find all arguments partial derivatives, which contain instrumental errors:

$$\frac{\partial C_p}{\partial T^A}, \ \frac{\partial C_p}{\partial T_i^P}, \frac{\partial C_p}{\partial T_0^P}, \frac{\partial C_p}{\partial T_i^{MgO}}, \ \frac{\partial C_p}{\partial T_0^{MgO}}, \frac{\partial C_p}{\partial m^P}, \frac{\partial C_p}{\partial m^{MgO}}.$$

These derivatives are called sensitivity coefficient which we mark respectively:

$$C_{T^A}, C_{T_i^P}, C_{T_0^P}, C_{T_i^{MgO}}, C_{T_0^{MgO}}, C_{m^P}, C_{m^{MgO}} \ .$$

The final values of sensitivity coefficients are found substituting the measured values and instrumental errors of corresponding instruments in the equation of the corresponding derivative.

The total absolute instrumental error looks like:

$$\Delta_{C_p} = \sum c_i \cdot \Delta_i, \quad (16)$$

where: Δ_i takes on values of corresponding normalized errors $\Delta_{T^A}, \Delta_{T_i^P}, \Delta_{T_i^{MgO}}, \Delta_{m^P}, \Delta_{m^{MgO}}$ and where $\Delta_{T^A}, \Delta_{T_i^P}, \Delta_{T_i^{MgO}}$ actually equal Δ_Σ of the measurement channel.

Theoretically found error values of the measuring of powder heat capacity depending on the temperature are presented in Figure 3.

The average error at different temperatures can be approximated with the polynomial dependence (17) (correlation coefficient R = 0,9855):

$$\Delta_{C_p} = -\,0{,}014 + 4\cdot10^{-4} \cdot T - 4\cdot10^{-7} \cdot T^2. \quad (17)$$

To evaluate a total error a series of experiments for powdered substances SiO_2, CaO, $K_2Cr_2O_7$ with known heat capacity and with different bulk density, molar mass and nanosize were carried out. Results are presented in Figure 3.

Empirical values of heat capacity calculated by the equation (7) for each temperature were compared with the values from reference data [26].

The maximum permissible measurement error was found to be 0,5% [27].

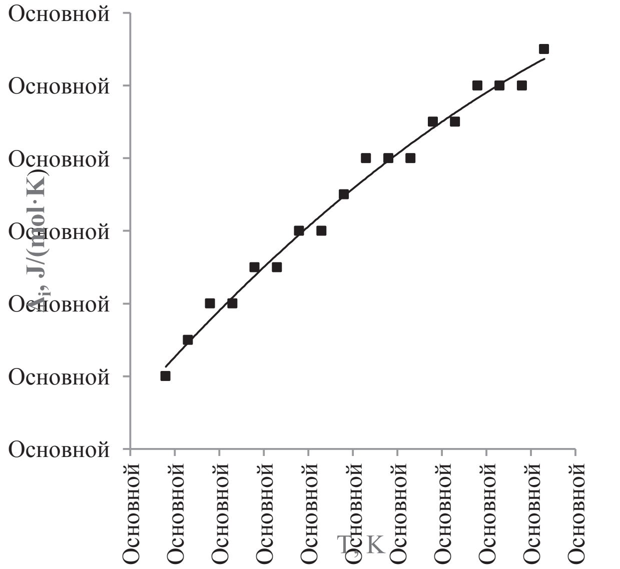

Fig. 3. Theoretically calculated ■ and approximated ——— values of instrumental error of the measuring of the heat capacity depending on the temperature of investigated powder.

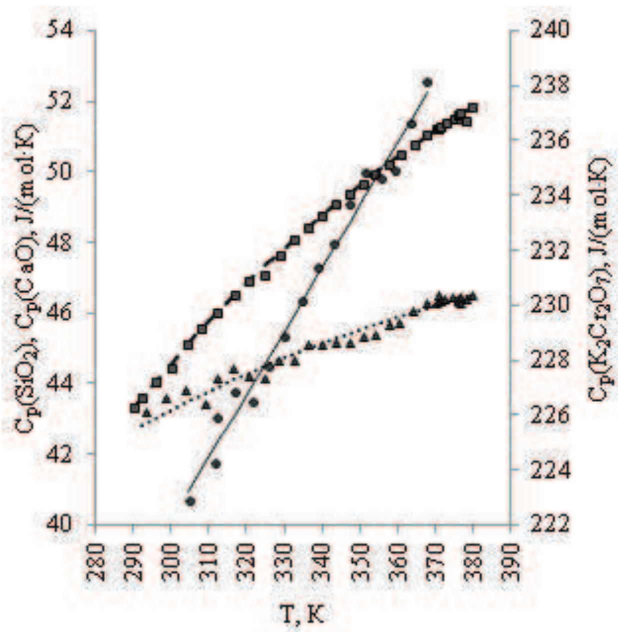

Fig. 3. Temperature dependence of empirical (C_p^{exp}) and reference (C_p^{ref}) heat capacity of powders SiO_2, CaO та $K_2Cr_2O_7$:

- - - C_p^{ref} (SiO_2); ■ – C_p^{exp} (SiO_2);
······ C_p^{ref} (CaO); ▲ – C_p^{exp} (CaO);
——— C_p^{ref} ($K_2Cr_2O_7$); ● – C_p^{exp} ($K_2Cr_2O_7$).

As it is seen from the figure 3, there are not any temperature dependence of the total error, that is the error has a random character. It can be evaluated with statistic method (type A):

For SiO_2 data σ[Δ] = 0,025 J/mol·K,
For CaO data σ[Δ] = 0,1 J/mol·K,
For $K_2Cr_2O_7$ data σ[Δ] = 0,5 J/mol·K.

It is apparent that the proposed way of finding the powder heat capacity contains method error for CaO, $K_2Cr_2O_7$ measuring since the total experimental error is by an order of magnitude greater than theoretical instrumental error. Whereas, for SiO_2 they are of the same order.

Used SiO_2 particles had the nanometer diameter of 30-50 nm, when CaO, $K_2Cr_2O_7$ had the diameter of about 100-200 nm.

We can conclude that the accuracy of the proposed method strongly depends on the powder particles size, deteriorating with the increase of particles diameter.

CONCLUSIONS

1. The proposed method of determining the heat capacity of highly dispersed powders does not require complex or non-standard equipment.

2. The method allows to determine the temperature dependence of the heat capacity with the total measurement error no greater than 0,5%, which was experimentally proven in the measurement of substances SiO_2, CaO, $K_2Cr_2O_7$ with known C_p in the temperature range of $15 \div 110^0$C.

3. The theoretically evaluated instrumental errors of the method according to the calculation procedure for indirect measurements were compared with the total experimental errors over the studied temperature range for all substances. It was shown that the increase of investigated particles diameter leads to the method error.

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Approach to decision support Intelligent Systems development based on Ontologies

Vasyl Lytvyn, Oksana Oborska, Roman Vovnjanka

Lviv Polytechnic National Univesity; e-mail: vasyl17.lytvyn@gmail.com

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Abstract. This article describes approach to the decision support intelligent systems development based on ontologies as part of such systems knowledge bases. Such systems are classified in terms of their functioning based on ontologies. Mathematical functioning of decision support intelligent systems is developed, which is based on ontologies. The term adaptive ontology is introduced to denote that. The adaptive ontology model is defined as classic model development by adding weights of importance of concepts and relations, stored in ontology.

Key words: adaptive ontology, intelligent agent, knowledge base, the weight of importance of concepts and relationships.

INTRODUCTION

Scientific research in the development and implementation of decision support intelligent systems (DSIS) lies in mathematical models development, methods and means of automated information systems development that are targeted to the areas of human activities that require logical reasoning, specific skills and experience, that is, based on knowledge. According to experts of information software systems development, a class of applications, which are necessary for solving such systems, is the most popular. The applications include decision tasks in such domains as disease diagnosing and technical problems; planning and monitoring activities; forecasting and classification of events; processing of natural language texts (quasi-summarization, quasi-annotation) and others.

The main component of DSIS is knowledge base (KB), which is formed according to the software on which functioning of the system is oriented. Traditional methods of knowledge engineering (getting knowledge from experts, data mining, machine learning, etc.) are not based on a system of verified and accepted standards, that is why are based on their basis KB and eventually lose their functionality due to low efficiency of their operation. Ontology engineering is used as knowledge engineering standard, as the result of which knowledge base ontology is received. Ontology - a detailed formalization of some given field of knowledge using conceptual scheme. This scheme consists of a hierarchical structure of concepts, relations between them, theorems and restrictions, which are taken in a particular software.

Using ontologies as part of KB DSIS helps to solve a number of methodological and technological problems that occur during the development of such systems. For Ukraine the typical problems are the lack of conceptual integrity and coherence of certain techniques and methods of knowledge engineering; lack of qualified specialists in this field; stiffness of developed software and its low adaptive capacity; complexity of DSIS implementation due to the psychological aspects. All this demonstrates and confirms the relevance of research problems using ontologies in building DSIS.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Research towards the use of ontologies in the development and functioning of information systems, including the DSIS, has began late last century and is developing intensively. Basic theoretical principles of formal mathematical models of ontology were developed in the works of T.Hruber [1], who proposed to consider ontology as three-dimensional tuple; N.Huarino [2] in his works described methods of ontology building and possible ways of its development; D.Sova introduced the conceptual graphs term [3] and M.Montes-Gomez used it for ontology presentation [4]. Analyzing the works in general we can conclude that research in the development and use of ontologies in the construction of applied information systems is actively developing. These facts show the topicality of the building DSIS-related problems based on ontologies as a subject of research.

Analysis of the main approaches, methods and tools for building DSIS and research areas using ontologies shows that the composition of these systems uses not all the possibilities of ontologies, especially during functionality simulation of such systems, although the advantages of ontologies usage in comparison with other methods of constructing KB are obvious since ontologies reflect objective knowledge and serve as a standard of engineering knowledge. In particular, there are some unresolved problems: modeling of decision-making processes and extraction of new knowledge based on ontologies; ontologies filling criteria; assessment of ontologies knowledge novelty and so on.

The purpose of the article

The article solves the problem of development and implementation of standardized methods of DSIS construction using the ontological approach to improve efficiency of KB and of the functioning of such systems.

THE BUILDING METRICS ON ONTOLOGY

Areas of decision support intelligent systems development

DSIS is software package designed to help the user make decisions about solving problems in particular software on the basis of knowledge of this area. DSIS has characteristics that are important in terms of modeling of the functioning: it contains a system of knowledge about the software which is presented as its model; mechanisms of reasoning, which are meta-procedures using knowledge to develop solutions; procedures of data mining that is a machine learning opportunity. DSIS functioning is a constant process of making decisions based on the current situations analysis. A typical functioning scheme of DSIS consists of the following three steps: 1) planning of targeted actions and decisions, that is the analysis of possible actions and choices of the one that best agrees with the purpose of the system; 2) reversed interpretation of the decision, that is the formation of a working algorithm to receive a response from the systems; 3) implementation of system response, resulting in changes in the external situation and the internal state of the system. The main component of DSIS is BR, the purpose of which is to store, organize and manage information about software and problems which occur in it. The most important parameter of KB is the quality and completeness of knowledge about the software, which it sets. The quality of KB depends on the structure and format of knowledge, its method of presentation. A clear and reasoned standard is required for wide implementation of any technology or methodology. In the field of KB development ontologies become that standard as a way to formal knowledge representation. Ontology is knowledge, formally reflected through conceptualization. Formal ontology consists of concepts (terms, notions), organized in a taxonomy, relations between the concepts, related axioms and rules of inference.

Given the foregoing, a formal ontology model O is:

$$\hat{O} = \left\langle \hat{C}, \hat{R}, F \right\rangle, \quad (1)$$

where: C – finite set of software concepts (notions, terms), which sets is set by the ontology O; $R : C \to C$. – finite set of relationships between concepts (terms, notions) of the given software; F – finite set of interpretation functions (axiomatization, restrictions) defined on ontology O concepts or relations.

The known four models of knowledge representation are used to build ontologies: frames for concept representation, semantic networks for relations representation, the second order predicate logic for axioms representations, and rules for building productive output rules. Semantic frames (concepts) network is called conceptual graph (CG).

Ontology model (1) specifies only explicit knowledge. According to the DSIS theory, the DSIS effectiveness depends on a combination of explicit and implicit knowledge. So this model needs to be developed to reflect its implied (implicit) knowledge available to the expert or user of the system. Such model development will provide quality DSIS functioning as the core of it is the KB ontology. For the decision-making process a language of requests to ontology is being developed, for example SPARQL language. However ontology containing tens of thousands of concepts and it is physically impossible to remember them all. An alternative to language of requests is metrics. It is proposed to build such metrics based on ontologies.

Current research for DSIS development is being conducted in two directions: 1) DSIS classification (output by precedents: Case-Based Reasoning); 2) DSIS activity planning (search for state goal in the space of states).

The choice of DSIS depends on the type of problem. Method for inference by precedents is effective when the main source of knowledge about the problem is experience, but not theory; the solution is not unique to a particular situation, and can be used in other cases; aim of solving the problem is to receive not guaranteed right solution, but the best among the possible. The inference, based on precedent, is a method of constructing DSIS, which makes decisions about the problem or situation by the analogies search results that are stored in a class database. From a mathematical point of view, the current situation S belongs to the class $Class_k$ among a plurality of N classes Class = {$Class1$, $Class2$, ..., $Class_N$ }, if the distance from S to this class is the smallest, i.e.

$$Class_k = \arg\min_i d(Class_i, S),\ i = \overline{1, N}. \quad (2)$$

DSIS planning activities must reach a state goal. The first step is to develop a plan to achieve this state with all possible alternative ways. The planning process is based on the principle of decomposition. The task of planning ZP contains three components: the set of states St, a plurality of actions A, states set goal $Goal$, i.e.

$$\text{ZP} = \left\langle St, A, Goal \right\rangle. \quad (3)$$

DSIS should be able to assess the condition and performance for effective planning. As we see, both types of DSIS require metrics. In the first case, it is required for vicinity class evaluation, in the second - to determine the relevance of states and actions. Efficiency of DSIS depends on the method of constructing the metrics [5].

Having analyzed the types of problems for which ontologies are used we conclude that all tasks can be divided into two subtypes. For the first type of problems it is essential, which values take properties of concepts. This includes tasks like diseases diagnostics, pattern recognition, and classification of phenomena on the basis of data collected so on. This type of problems should be named the feature problems. For the other types of problems the values of concepts are not essential; rather their semantics or concepts frequency of use in the text, etc. These problems include clustering information resources, text classification according to the UDC, intelligent search engines, quasi-summarization and quasi-annotation of text documents. This type of problems should be named the semantic problems. As the result we receive the division of DSIS into two dimensions (the direction of the development and operation of space), as shown on (*Fig. 1*). In each quarter the problems are listed that fall to the appropriate type.

DSIS needs to build metrics for the effective functioning, with the help of which it is possible to

determine the relevance classes or classes. Construction of such metrics depends on the type of problems: whether they are semantic or feature problems. Thus, there are four types of problems that are solved using DSIS. The cut in the field of research requires two different functional models (class search and planning activities), the cut by problem type - using all sorts of metrics for finding their solution and evaluating the quality of the obtained solutions. We will consider all these types of problems, firstly introducing the concept of adaptive ontologies (AO).

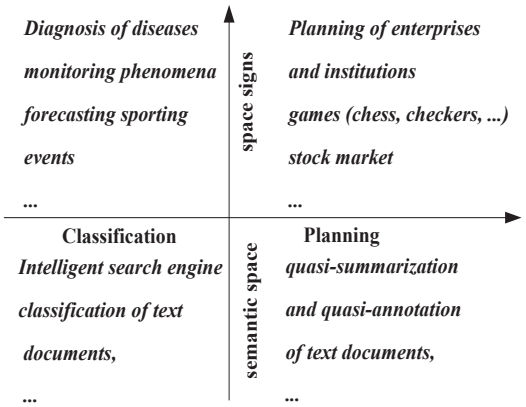

Fig. 1. *The types of problems for solving which the DSIS is used.*

The effectiveness of KB ontology adaptation to the characteristics of software define elements of its structure and mechanisms of adaptation through learning during operation. One approach to implementing such mechanisms is automated weighing of KB concepts and semantic relations between them during self learning. This is the role of concepts importance and relationships. Weight of concepts importance (link) - a numerical measure which describes the significance of certain concepts (link) in a particular software and changes dynamically according to certain rules while operating the system. It is proposed to expand an ontology model (1) by bringing its formal description of weight of concepts importance and relations [6,7]. This ontology is defined as:

$$\hat{O} = \left\langle \hat{C}, \hat{R}, F \right\rangle, \qquad (4)$$

where: $\hat{C} = \langle C, W \rangle$, $\hat{R} = \langle R, L \rangle$, W – weight of concepts importance C, L – weight of relations importance R.

Ontology defined this way is called adaptive, i.e. one that adapts to software modifications with the help of setting scales of weight of concepts importance and relations between them. Such ontology is clearly given as a weighted CG. Therefore, metrics is based on such graphs.

Advantages of models (4) over (1) are: 1) the ability to build metrics based on ontologies; 2) the ability to adapt to the DSIS knowledge base to the user needs; 3) the ability to set the importance of knowledge in terms of software expert; 4) AO unlike conventional ontology reflects not only the explicit knowledge, but also implicit (hidden); 5) data mining methods (decision trees, Bayesian networks, k-nearest neighbors) is a special case of AO depending on the setting of weight of concept importance rules and relations. In terms of building KB DSIS we receive such an approach: expert or the system user receive a ready KB, the core of which is the ontology, and their task is only to set up this KB for themselves by setting scales of importance of its elements.

Metrics based on adaptive ontology

Elasticity The process of DSIS functioning for classification problems is that some current situation S belongs to the class ZClass: $S \to \text{Class}$. To do this, the distance between the current situation and particular $d_i = d(S, \text{Class}_i)$. The situation S belongs to the class to which distance is smallest. It is proposed to carry out a decision that corresponds to this class. Mostly classification methods are reduced to induction of decision trees (DT) or nearest neighbor algorithm, supplemented by knowledge of the software. As for adapting and using the found solution, this problem is still not formalized enough and significantly dependent on software. It is proposed to use the AO for classification, i.e. to design classes and the current situation on the ontology software; introduce software metrics within the ontology for the required distance search [5, 8].

For semantic problems it is proposed to determine the distance between the class and the situation as the distance between the "important" concept of class and current situation. Since AO is shown as a weighted CG, such concept is called the weights center of the respectively weighted CG. If C^j_{class} - class weights center, C^k_s – weights center of the current situation, then the distance between that class and the current situation is defined as $d(Class, S) = d\left(C^j_{class}, C^k_s\right)$.

From a mathematical point of view: the weights center of CG is a concept from which the average distance to all other concepts is the smallest. Obviously, in a manner determined distance will depend on how we ask the distance between two adjacent vertexes CG. It is proposed to determine the distance between vertices that are connected as

$$d_{ij} = \frac{Q}{L_{ij}\left(W_i + W_j\right)}, \qquad (5)$$

where: W_i and W_j – importance weights of vertexes C_i and C_j respectively; L_{ij} – weight of importance of link between the vertexes; Q – constant, which depends on the particular ontology. It is assumed that $L_{ij} = \infty$, then $d_{ij} = 0$.

Next, the weight centers of corresponding CG are found. Weights center $\bar{d}_i$ is the CG vertex, for which the average distance and d are the smallest: $\bar{d}_{i^*} = \min_i \bar{d}_i$. The average distance and $\bar{d}_i$ for the vertex C_i is calculated using the formula:

$$\bar{d}_i = \frac{\sum_{j=1, j\neq i}^{n} d^*_{ij}}{n-1}, \qquad (6)$$

where : n – the number of vertices; d^*_{ij} – the shortest path between vertices C_i and C_j, which can be found by known algorithms, such as Floyd-Uorshalla, Ford, Dijkstra

algorithms. The proposed distance satisfies the three axioms of metrics.

Then the metric was created to solve the classification problems in the feature space. Let the set of classes Class=$\{Class_1, Class_2,\ldots, Class_N\}$ be represented by attributes $X=\{x_1, x_2, \ldots, x_M\}$. D_i – domain of attribute x_i; w_{il} – weight of attribute importance x_{il} in class $Class_i$. The value of attribute x_i we denote by $z_i = z(x_i)$. So, $Class_i \leftrightarrow X_i = \{x_{i_1} = z_{i_1}, x_{i_2} = z_{i_2}, ..., x_{i_k} = z_{i_k}\}$, where $z_{i_j} \in D_{i_j}$. Then the distance between the class $Class_i$ and the current situation S is defined as:

$$d_i = \sum_{i_l \in \overline{I}_i} \varphi\left(z_{i_l}, z_{i_l}^S\right), \qquad (7)$$

where: z_{i_l} – the value of attribute x_{i_l} in class $Class_i$; $z_{i_j}^S$ – значення властивості x_{i_l} поточної ситуації S; $\overline{I}_i$ – set of indexes of the most important attributes of the class $Class_i$, $\overline{I}_i = \overline{I}_{i1} \cup \overline{I}_{i2} \cup ... \cup \overline{I}_{iN_i}$, N_i – number of properties that should be considered in order to make a decision regarding affiliation of S to the class $Class_i$,

$$\overline{I}_{i1} = \left\{ i_{s1} \middle| i_{s1} = \arg\max_{i_l \in I_i} w_{i_l} \right\}, \ \overline{I}_{i2} = \left\{ i_{s2} \middle| i_{s2} = \arg\max_{i_l \in I_i / i_{s1}} w_{i_l} \right\},$$

$$\ldots \ \varphi(\xi, \eta)$$

when: trying to solve one single problem, we can choose as function any known metrics (eg, Euclidean, Manhattan, lemming, Zhuravlev, etc.), depending on what data is used (quantitative, qualitative or mixed) [9-12].

$v\left(St(i)\right)$ is valuation of condition $St(i)$ and a_{ij}^k a transition from a condition of $St(i)$ into $St(j)$ with the use of alternative α_k; $v\left(a_{ij}^k\right)$ valuation of an action a_{ij}^k. Condition of the goal *Goal* is determined by the fact that some subset of attributes X must reach certain values $z(x, Goal) \ \forall x \in X$.

To evaluate the condition of $St(i)$ we need to display Y_i set of attributes and their values of the condition $St(i)$ into the set of attributes and their values of the condition *Goal*, using KB ontology rules (SWRL), ie: $\psi : Y_i \xrightarrow{o} X$. Then the evaluation of the condition $v(St(i))$ can be calculated as following: $v(St(i)) = d(St(i), Gool) = \sum_{x \in X_w} \varphi(z(\psi(x), St(i),$

where^ X_W - set of attributes with the largest weights in the AO, function φ is the same as in (7). The smaller the evaluation of condition is the better condition. The power of set $|X_W|$ is defined by the system user.

To select IDSS actions we should take into account the rationality of user is behavior, namely the effort to minimize the cost of resources for the attainment of the goal. Each alternative is characterized by resource costs and lifetime. Information on this alternatives and resources is stored in the ontology. All information about the importance of attributes is contained in the database. Of course, some new alternatives may appear because DSS module includes the ontology replenishment.

The assessment of the action is directly proportional to the resource costs:

$$v\left(a_{ij}^k\right) = E \cdot g_{ij}^k,$$

where: E – a scalar quantity.

The decision about the choice of alternative-based action we perform according to the formula specified:

$$o_i\left(a_{ij}^k\right) = \delta\left(v\left(a_{ij}^k\right), v\left(St(j)\right)\right).$$

By using methods suitable for solving such problems, we find a solution in the form of the transition from the initial to the final condition:

$$St(j) = a\left(St(i), o_i\right), \ \Theta\left(St(0), \vec{o}\right) \Rightarrow \max(\min).$$

If we talk about planning semantic problems it's quite difficult to say anything in advance about the condition of the goal *Goal*.

For example, the condition of the goal *Goal* for the problem of quasi -abstracting is a quasi-referent, but we can only imagine what it will be like. The evaluation of the condition coincides with the evaluation of the importance of semantic units (word, token, sentence) depending on the task. The process of creating metrics for such tasks must be based on weighting TF-IDF measure by ontology software:

$$v(St) = (\text{TF-IDF}) \cdot W.$$

This evaluation has significant advantages over the others, because it simultaneously takes into account both the frequency analysis of the use of terms in text (TFIDF), and software specifics. The new condition for the quasi-referential tasks consists in adding new sentences to quasi-referent.

THE MAIN RESULTS OF THE RESEARCH

Approbation of metrics

Described IDSS consists of the following components: a knowledge base (KB) with AO as a core; Database (DB), in which the set of classes and corresponding solutions are stored depending on the type of the task, weights of the importance of AO concepts, types of ratios and weight of their importance, value of characteristics and the history of such values (for planning tasks); tasks solving control module (uses the built metrics in accordance to the task); knowledge replenishment module (builds, teaches and optimizes the ontology). To implement these components the following tools were selected: ontology editor Protégé OWL API to build ontology; SWRL (included as a separate Protégé module) – for saving rules of knowledge base; a database management system (7) MySQL to build a database. Programming languages PHP, Python, Java, C # were used to build the control module and the knowledge replenishment module in accordance to the IDSS function (purpose) [13-15].

IDSS was developed for semantic tasks such as intelligent search system (ICS) and IDSS text documents classification. The search engine is called intelligent if it makes context-based searches. Classification IDSS belongs to such systems. Indeed, the text unit in accordance to which the search is conducted (sentence, phrase, phrases, etc.) is the current situation, which we

will call standard. The found text documents are classes, ranked (graded) according to the distance to the standard.

The weights of ontology concepts relating to the subject matter are taken as weights, used when finding the distance. Let us show the efficiency of the IDSS functioning on the example of analysis of the scientific articles abstracts. Let's explore two abstracts from the journal «Physical-chemical Mechanics of Materials».

1. The correlation between difractometric inverstigations and calculations, based on the model of rigid spheres, allowed us to make prediction of the change of the surface tension and to evaluate the steel wettability by extremum of a continuous function of structural melt factor. The influence of stainless steel elements laser doped into the surface on structural factors of melts Pb and Li Pb was investigated.

2. The damaging of power plant equipment, made of stainless austenitic steels is considered. It has been found that initiation of intergranular stress corrosion cracks in the weld region of the welded joints made of this steel is caused by interaction of 3 factors – the determined degree of basic metal sensitization, high service stress, that is higher than the material yield strength and the increased oxygen concentration in the heat carrier.

The value of concepts weights and relations is taken from the developed materials science ontology based on the frequency method. Using the formula (5), which assumed that Q = 50, we get weighed KG of these abstracts, shown in (*Fig. 2*):

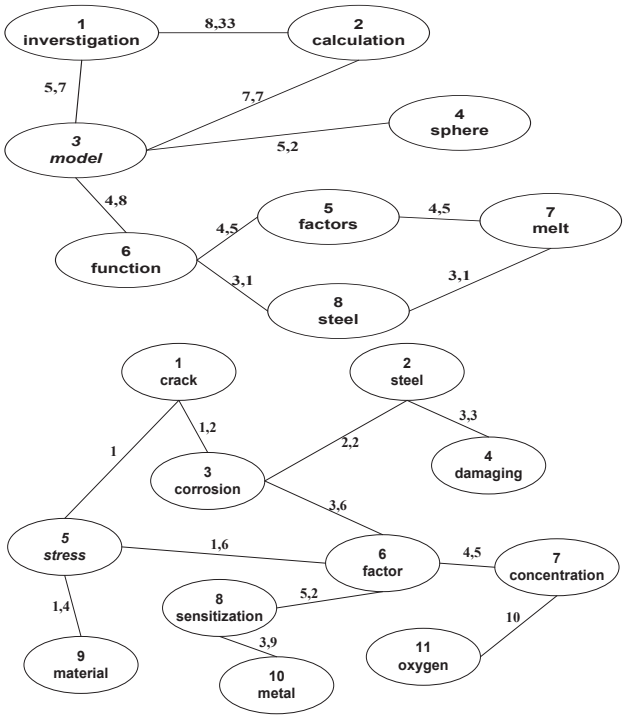

Fig. 2. The weighted conceptual graphs of two abstracts.

Indexes are marked above the concepts. We use the Floyd–War shall algorithm and formula (6) to define that the canter of weights are: $C^1 = \{3\} = \{\text{'model'}\}$ $\bar{d}_3 = 7,37$, $C^2 = \{5\} = \{\text{'stress'}\}$, $\bar{d}_5 = 5,8$. The search is conducted for the word ‘corrosion’, that is this concept is considered to be the center of weights of the current situation, while centers of abstract weights are centers of classes weights. Since the concept of ‘corrosion’ is represented in the 2nd abstract, the distance to this abstract is equal to the distance between 'corrosion' and the center of weights of this abstract: $d(\text{Pr}_2, S) = d(C^3, C^5) = 2,2$. The distance for the first abstract must be found by means of the ontology-based techniques. According to the materials science ontology the path from 'corrosion' to 'model' is as follows: ‘corrosion’ - ‘physical_process’ - ‘process’ - ‘model’.

Considering the weights of concepts and relations (the first two are hierarchical, when the third is functional) we get the following: ($d(\text{Pr}_1, S) = 4,6$. By analogy, we find the distance from the keyword ‘corrosion’ to other abstracts.

The developed method is not an alternative to the keyword search of information, but its addition. If the keyword search fails to produce the expected results, the developed contextual ontology-based search must be used. Since ontology defines scientific knowledge, this kind of search makes sense only for scientific information. So in our case, the result of the search for the keyword 'corrosion' would be only the second abstract. We offer the user to look through the article which corresponds with the first abstract [16-18].

For feature problems, IDSS plan of pipeline diagnosis and upgrading was developed. The challenge for IDSS (P) is to enter the state Goal by using this resource and knowledge software stored in its ontology: $P: St(0) \xrightarrow{G,O} Goal$. For states evaluation the lifetime of the pipeline (r) was applied. For action evaluation - the resource consumption g for the transition from state to state was applied. Then the formula (9) is simplified as follows: $o(a_{ij}^k) = \frac{r_j^k}{g_{ij}^k}$, where g_{ij}^k - the resource consumption for the transition from to state $St(i)$, using alternative α_k, r_j^k – lifetime of the state $St(j)$, for alternative α_k. To process the pipe three sub-tasks must solved (*preparation, coating, protection*), the first of which is divided into four subtasks (*opening tube surface, removing the protective coating, degreasing, priming*). To solve each subtask the alternative solutions must be found. For subtask of removal of protective coating one of three alternatives (mechanical, chemical, thermal) can be chosen. All this information is stored in the materials science ontology [19-20].

The rationality of activities planning is formulated as follows: how to extend the lifetime of the pipeline at a minimum cost, taking into account that: 1) the electrochemical corrosion of the pipe is the main limiting factor; 2) an economic effect that the ISDD user gets from the operation of the pipeline; 3) the cost of corrosion protection, 4) the indicative dates for trouble-free operation of the pipeline and taken measures of its anti-corrosion protection known from expert assessments, standards, data non-destructive testing and technical diagnostics. *IF ((it is time to restore the coverage) OR (It was the event of damage to the coating) OR (the measured parameters exceed the allowable threshold))*

AND (needed resources are available) TO (Run coverage replacement). To find this information the articles from scientific journal Physical-chemical Mechanics of Materials were analyzed. Some abstracts are written in the developed ontology using SWRL-rules. On the whole, the following model was produced:

$$\begin{cases} \Theta = \sum_{i=0}^{N-1} o_i\left(a_{ij}^k\right) \to \max, \\ r \geq r_e, \\ \sum_{i=0}^{N-1} g_{ij}^k \leq G, \end{cases} \quad (8)$$

where: $r = \min_j r_j$, r_e – term exploitation the desired.

The problem (8) can be solved by functional equations approach, suitable for solving problems of dynamic programming. Using AO as part of IDSS KB enables to reduce the problem of planning to the problem of dynamic programming.

CONCLUSIONS

As a result of this research the ontology-based method of creating and improving the efficiency of the intelligent decision support systems has been developed. This was achieved through the use of developed earlier software, based on the use of the ontologies in such systems, and adaptation ontologies to the specific problems of the domain. The structure of traditional ontologies was modified by introducing the weights of importance of concepts and relations. This made it possible to adapt the ontology to the specific problems of domain and to the needs of system user through setting up these weights. This model of ontology specifies not only explicit, but implicit knowledge. Mathematical software was developed for functioning of ontology-based intelligent decision support systems, which helped to formalize the decision making process of such a system. Unlike other metrics, this semantic metric based on adaptive ontology takes into account not only their taxonomy of the concepts, but also the causal dependence between them. The mathematical software based on the automated determination of set of properties, according to the values of which the decision support process is implemented. Based on the built models, methods and algorithms, the software of the intelligent decision support systems enables to implement individual components and functional modules of the intelligent decision support systems.

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Iterative method of neural elements synthesis with generalized threshold activation function

F. Geche[1], A. Batyuk[2], O. Melnyk[1], T. Spenyk[1]

[1]Uzhhorod National University, e-mail: fgeche@hotmail.com
[2]Lviv Polytechnic National University, e-mail: abatyuk@gmail.com

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Abstract. Present work considers the neural elements (NE) with generalized threshold activation function and represents iterative method of their synthesis. Algorithm of vectors finding for structures of the neural elements with generalized threshold activation function was developed, and the sufficient condition of Boolean function unreliazability on such neural elements was discovered.

Key words: neural element, boolean function, system of characters, structure vector, algorithm of synthesis.

INTRODUCTION

Last years could be called the period of rapid development of technical facilities and informational technologies with high values of productiveness, which resulted in formation and implementation of more effective methods in data processing and analysis, as well as new methods of resolving the complicated applied tasks. In connection with this we can monitor higher interest to neural structures that have found broad application in different spheres of human activity – recognition of images [1-3], forecasting [4-7], business [8,9] , medicine [10], technical appliances [11-13].

Considerable resources that were invested in creation of software and hardware of artificial neural networks, both as broad application of neurolike structures witness about the fact that problem of synthesis of neural elements with different activation functions and construction of logical schemes from them are actual and practically important issues.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Task of neural structure synthesis with discrete functions of activation contains two main subtasks:

– the first – to check whether a discrete function could be implemented by means of one neural element with selected activation function, and, if the answer is positive, then how to find the vector of structure for appropriate neural element?;

– the second – in case if the function could not be implemented by means of one neural element with selected activation function, then how to determine the configuration (the topology) of artificial neural network, which implements the present function, how to achieve the required reliability in network functioning, how to reduce the time of network learning and so on?

Both the first and the second subtasks of neural structures synthesis with different functions of neural elements activation were actively researched and different methods, algorithms and measures of technical implementation were developed for their solution in works of well-known foreign and national scientists [14-19].

The task of synthesis of neural elements with generalized threshold activation functions was often considered in [20], while the synthesis of such elements by method of approximation was considered in [21].

The main disadvantage of approximation method is inability to establish such order of approximation that will provide the synthesis of appropriate NE for present Boolean neural function $f(x_1,\ldots,x_n)$ relating to fixed generelized threshold activation function. By means of present method in general case we could not indicate the order of aproximation, on the basis of which the unambiguous answer could be given on question whether present Boolean function is implemented by one NE relating to specified threshold activation function?

Therefore, improvement and development of the new synthesis methods of one NE with generalized threshold activation functions, as well as synthesis of neural networks of this elements are actual tasks and are grounded by the fact that at effective methods of their synthesis they could be successfully used for resolving the entire class of applied tasks: coding and information transfer, classification and recognition of discrete signals and images, forecasting of time series and so on.

OBJECTIVES

Objective of the article is the development of effective method of synthesis of neural elements with generelized threshold functions over the field of real numbers R .

THE MAIN RESULTS OF THE RESEARCH

Mathematical model of neural element with generalized threshold activation function.

Let $H_2 = \{-1,1\}$ – cyclic group of 2-nd order, $G_n = H_2 \otimes \ldots \otimes H_2$ – direct product n cyclic group H_2

and $X(G_n)$ – group of characters [22,23] of group G_n over the field of real numbers R.

Boolean function $f(x_1,\ldots x_n)$ from n variables in the alphabet $\{-1,1\}$ uniquely implements indication $f{:}G_n \to H_2$.

Let us consider 2^n-dimensional vector space $V_R = \{\varphi \,|\, \varphi : G_n \to R\}$ over the field R. Elements χ_i $(i = 0,1,2,\ldots,2^n-1)$ of group $X(G_n)$ form orthogonal basis of space V_R [22, 24]. Consequently, function $f \in V_R$ definitely could be written as:

$$f(\mathbf{g}) = s_0\chi_0(\mathbf{g}) + s_1\chi_1(\mathbf{g}) + \ldots + s_{2^n-1}\chi_{2^n-1}(\mathbf{g}). \qquad (1)$$

Vector $\mathbf{s}_f = (s_0, s_1, \ldots, s_{2^n-1})$ is named the spectrum of Boolean function in system of characters $X(G_n)$ (in system of basis functions of Walsh-Hadamard) [24-27].

Lets define function on the set $R \setminus \{0\}$:

$$\mathrm{Rsign}x = \begin{cases} 1, & if\ x > 0, \\ -1, & if\ x < 0. \end{cases} \qquad (2)$$

From different characters $X(G_n)$, except the main one, we will build m-element set $\{\chi_{i_1},\ldots,\chi_{i_m}\}$ and relating the chosen systems of characters we will consider the following mathematical model of neural element:

$$f(x_1(\mathbf{g}),\ldots,x_n(\mathbf{g})) = \mathrm{Rsign}\Big(\sum_{j=1}^{m}\omega_j\chi_{i_j}(\mathbf{g}) + \omega_0\Big), \qquad (3)$$

where vector $\mathbf{w} = (\omega_1,\ldots,\omega_m;\omega_0)$ is named as vector of neural element structure relating to $\{\chi_{i_1},\ldots,\chi_{i_m}\}$ i $\mathbf{g} \in G_n$.

Remark. System of characters $\{\chi_{i_1},\ldots,\chi_{i_m}\}$ for given Boolean function f, as a rule, we shall define as follows: $\forall i \in \{i_1,\ldots,i_m\}$ and $\forall j \in \{1,2,\ldots 2^n-1\}\setminus\{i_1,\ldots,i_m\}$ spectral coefficients s_i and s_j are satisfying the inequality $|s_i| \geq |s_j|$, $|a|$ – module of real number a.

Let $\mathrm{w}(\mathbf{g}) = \omega_1\chi_{i_1}(\mathbf{g}) + \ldots + \omega_m\chi_{i_m}(\mathbf{g}) + \omega_0$. If $\mathbf{w} = (\omega_1,\ldots,\omega_m;\omega_0)$ is a vector of NE structure relating to system of characters $\{\chi_{i_1},\ldots\chi_{i_m}\}$ of group G_n over R, which implements Boolean function $f : G_n \to H_2$, then from (2) and (3) immediately follows that:

$$\forall \mathbf{g} \in G_n \quad \mathrm{w}(\mathbf{g}) \neq 0. \qquad (4)$$

Further we will consider only such neural elements, vector structures of which satisfy the condition (4). Set of all such $m+1$-dimensional real vectors that satisfy the condition (4) we will mark by means of $\mathrm{W}_{m+1} = \mathrm{W}_{m+1}(\chi_{i_1},\ldots\chi_{i_m})$.

It is obvious that the neural element relating to the system of characters $\{\chi_1, \chi_2, \chi_4, \ldots, \chi_{2^{n-1}}\}$ coincides with the threshold element [28].

It was proved in the work [21]: if NE with vector of structure $\mathbf{w} \in \mathrm{W}_{m+1}$ relating to the system of characters $\{\chi_{i_1},\ldots\chi_{i_m}\}$ implements Boolean function f, then for random Boolean function $h : G_n \to H_2$ $(h \neq f)$ inequality is fulfilled:

$$(\mathbf{w}, \mathbf{s}_f(X)) > (\mathbf{w}, \mathbf{s}_h(X)). \qquad (5)$$

Similarly as in the threshold logics, here also the question arises if given Boolean function is realized $f(x_1,\ldots,x_n)$ by one NE relating to the chosen system of charecters $\{\chi_{i_1},\ldots\chi_{i_m}\}$, and if so, then how its related structure vector could be found?

In order to find the structure vector NE with generalised threshold activation function, we will present the following iteration method.

Iteration method of neural element synthesis with generalised threshold activation function.

Lets assume that the Boolean function $f(x_1,\ldots,x_n)$ $(f : G_n \to H_2)$ is realized by one NE relating to the system of characters $X = \{\chi_{i_1}, \chi_{i_2}, \ldots, \chi_{i_m}\}$ group G_n over R. If vector of NE structure is designated as $\mathbf{w} = (\omega_1,\ldots,\omega_m;\omega_0)$, then

$$f(x_1(\mathbf{g}),\ldots,x_n(\mathbf{g})) = \mathrm{Rsign}(\omega_1\chi_{i_1}(\mathbf{g}) + \ldots + \omega_m\chi_{i_m}(\mathbf{g}) + \omega_0)$$

and

$$\forall \mathbf{g} \in G_n \quad \mathrm{w}(\mathbf{g}) = \omega_1\chi_{i_1}(\mathbf{g}) + \ldots + \omega_m\chi_{i_m}(\mathbf{g}) + \omega_0 \neq 0.$$

Lets consider the random $m+1$-dimensional valid vector $\mathbf{v}_k = (v_1^{(k)},\ldots,v_m^{(k)},v_0^{(k)})$, for which $\forall \mathbf{g} \in G_n$ $\mathbf{v}_k(\mathbf{g}) \neq 0$. From vector $\mathbf{v}_k$ we should go to the vector $\mathbf{v}_{k+1}$ in such way that $\rho(\mathbf{v}_{k+1},\mathbf{w}) < \rho(\mathbf{v}_k,\mathbf{w})$, where $\rho(\mathbf{v},\mathbf{w})$ – is Euclidean distance between vectors $\mathbf{v}$ and $\mathbf{w}$.

Lets define as vector of error the value:

$$\boldsymbol{\varepsilon}_k = \mathbf{w} - \mathbf{v}_k, \qquad (6)$$

and vector of grouth – $\mathbf{z}_k = \mathbf{v}_{k+1} - \mathbf{v}_k$.

Then:

$$\boldsymbol{\varepsilon}_{k+1} = \boldsymbol{\varepsilon}_k - \mathbf{z}_k. \qquad (7)$$

For convergence of process it is required that $|\boldsymbol{\varepsilon}_k|$ was bigger than $|\boldsymbol{\varepsilon}_{k+1}|$, that is the value $\Delta(\boldsymbol{\varepsilon}_k,\boldsymbol{\varepsilon}_{k+1}) = |\boldsymbol{\varepsilon}_k|^2 - |\boldsymbol{\varepsilon}_{k+1}|^2$ should be positive. From

equalities (6), (7) and at condition that $\Delta(\boldsymbol{\varepsilon}_k, \boldsymbol{\varepsilon}_{k+1}) > 0$ it follows that:

$$2(\mathbf{z}_k, (\mathbf{w} - \mathbf{v}_k)) - |\mathbf{z}_k|^2 > 0. \quad (8)$$

If the vector of growth $\mathbf{z}_k = \mathbf{v}_{k+1} - \mathbf{v}_k$ is defined in such a way that the inequality (8) was true, then vector:

$$\mathbf{v}_{k+1} = \mathbf{v}_k + \mathbf{z}_k \quad (9)$$

will satisfy the condition $\rho(\mathbf{v}_{k+1}, \mathbf{w}) < \rho(\mathbf{v}_k, \mathbf{w})$.

Lets move to definition of vector $\mathbf{z}_k$. Function that is realized by neural element with structure vector $\mathbf{v}_k = \left(v_1^{(k)}, \ldots, v_m^{(k)}, v_0^{(k)}\right)$ relating to characters system $X = \{\chi_{i_1}, \chi_{i_2}, \ldots, \chi_{i_m}\}$ we shall designate by means of $h_k(x_1, \ldots, x_n)$, and its characteristic vector relating to X with $\mathbf{s}_{h_k}(X)$. Vector of increment $\mathbf{z}_k$ is set as follows:

$$\mathbf{z}_k = \theta_k \left(\mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right), \quad (10)$$

where θ_k – some positive value. Value θ_k should be designated in such a way that inequality was true (8). Lets substitute the value $\mathbf{z}_k$ from (10) to inequality (8). Then:

$$2\theta_k \left(\mathbf{w} - \mathbf{v}_k, \mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right) - \theta_k^2 \left|\mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right|^2 > 0. \quad (11)$$

The first term in the last inequality is not negative and equals to zero only in case when $f = h_k$. Indeed,

$$\left(\mathbf{w} - \mathbf{v}_k, \mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right) = (\mathbf{w}, \mathbf{s}_f(X)) - (\mathbf{w}, \mathbf{s}_{h_k}(X)) + \\ + (\mathbf{v}_k, \mathbf{s}_{h_k}(X)) - (\mathbf{v}_k, \mathbf{s}_f(X)),$$

and on the basis (5) we could assume, that every term on the right side of equality is positive, if $f \neq h_k$ and equals to zero, when $f = h_k$. Left side (11) is a square trinomial relating to θ_k and, obviously, the square trinomial acquires the biggest value when:

$$\theta_k^* = \frac{\left(\mathbf{w} - \mathbf{v}_k, \mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right)}{\left|\mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right|^2}, \quad (12)$$

and this value is positive. The right part of the last equality includes the unknown vector $\mathbf{w}$, and this means that correlation (12) could not be used for finding of θ_k. Lets choose for θ_k the following value:

$$\theta_k^0 = \frac{\left(\mathbf{v}_k, \mathbf{s}_{h_k}(X) - \mathbf{s}_f(X)\right)}{\left|\mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right|^2}, \quad (13)$$

and show that if $\theta_k = \theta_k^0$ inequality (11) is true. If in (11) instead of θ_k we shall substitute θ_k^0, then after transformations we obtain:

$$\Delta(\boldsymbol{\varepsilon}_k, \boldsymbol{\varepsilon}_{k+1}) = \frac{\left(\mathbf{v}_k, \mathbf{s}_{h_k}(X) - \mathbf{s}_f(X)\right)^2}{\left|\mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right|^2} + \\ + \frac{2\left(\mathbf{v}_k, \mathbf{s}_{h_k}(X) - \mathbf{s}_f(X)\right)\left(\mathbf{w}, \mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right)}{\left|\mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right|^2}.$$

According to inequality (5) and condition $\forall \mathbf{g} \in G_n$ $\mathbf{v}_k(\mathbf{g}) \neq 0$ both terms in numerator are positive, if $f \neq h_k$, and equal to zero, if $f = h_k$. In the last case vector $\mathbf{v}_k$ implements function f and process of synthesis NE is completed.

Consequently, vector:

$$\mathbf{v}_{k+1} = \mathbf{v}_k + \theta_k^0 \left(\mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right),$$

satisfies inequality $\rho(\mathbf{v}_{k+1}, \mathbf{w}) < \rho(\mathbf{v}_k, \mathbf{w})$, if $f \neq h_k$. Similarly as in [28] on the basis of inequality $\rho(\mathbf{v}_{k+1}, \mathbf{w}) < \rho(\mathbf{v}_k, \mathbf{w})$ we can show that for neurofunction f sequence of vectors $\{\mathbf{v}_k\}$ coincides to the structure vector $\mathbf{w}$ of function f.

On every step of iteration vector $\mathbf{v}_k$ must satisfy the condition:

$$\forall \mathbf{g} \in G_n \quad \mathbf{v}_k(\mathbf{g}) \neq 0. \quad (14)$$

If during the process of iteration for θ_k we shall always choose θ_k^0, then such moment could come when condition (14) is not true. To avoid such situation, for scalar value θ_k we should specify such area, for which $\Delta(\boldsymbol{\varepsilon}_k, \boldsymbol{\varepsilon}_{k+1}) > 0$ and for θ_k one can always chose such value, for which (14) is true. Let $\theta_k = 2\theta_k^0$. Lets enclose this value in (11). Then:

$$\Delta(\boldsymbol{\varepsilon}_k, \boldsymbol{\varepsilon}_{k+1}) = \\ = \frac{4\left(\mathbf{v}_k, \mathbf{s}_{h_k}(X) - \mathbf{s}_f(X)\right)\left(\mathbf{w} - \mathbf{v}_k, \mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right)}{\left|\mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right|^2} - \\ - \frac{4\left(\mathbf{v}_k, \mathbf{s}_{h_k}(X) - \mathbf{s}_f(X)\right)^2}{\left|\mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right|^2} = \\ = \frac{4\left(\mathbf{v}_k, \mathbf{s}_{h_k}(X) - \mathbf{s}_f(X)\right)\left(\mathbf{w}, \mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right)}{\left|\mathbf{s}_f(X) - \mathbf{s}_{h_k}(X)\right|^2}.$$

From the last equality on the basis of (5) and (14) immediately follows that when $f \neq h_k$, then $\Delta(\boldsymbol{\varepsilon}_k, \boldsymbol{\varepsilon}_{k+1}) > 0$ and $\Delta(\boldsymbol{\varepsilon}_k, \boldsymbol{\varepsilon}_{k+1}) = 0$, only in case when $f = h_k$. Consequently, $\Delta(\boldsymbol{\varepsilon}_k, \boldsymbol{\varepsilon}_{k+1}) =$

$= 2\theta_k\left(\mathbf{w}-\mathbf{v}_k, \mathbf{s}_f(X)-\mathbf{s}_{h_k}(X)\right)-\theta_k^2\left|\mathbf{s}_f(X)-\mathbf{s}_{h_k}(X)\right|^2$ takes positive value at any value of θ_k in interval $[\theta_k^0, 2\theta_k^0]$ and present interval sets the required area for θ_k.

Lets show that if $\theta_k \in (\theta_k^0, 2\theta_k^0]$, then $\mathbf{s}_{h_{k+1}}(X) \neq \mathbf{s}_{h_k}(X)$. Lets assume the opposite, that is $\mathbf{s}_{h_{k+1}}(X) = \mathbf{s}_{h_k}(X)$. Then on the basis of inequality (5) from condition $\mathbf{s}_{h_k}(X) \neq \mathbf{s}_f(X)$ we have:

$$\left(\mathbf{v}_{k+1}, \mathbf{s}_{h_k}(X)-\mathbf{s}_f(X)\right) > 0. \quad (15)$$

If in inequality (15) $\mathbf{v}_{k+1}$ is changed by expression $\mathbf{v}_k + \theta_k\left(\mathbf{s}_f(X)-\mathbf{s}_{h_k}(X)\right)$, then we get:

$$\left(\mathbf{v}_k, \mathbf{s}_{h_k}(X)-\mathbf{s}_f(X)\right)-\theta_k\left|\mathbf{s}_f(X)-\mathbf{s}_{h_k}(X)\right|^2 > 0. \quad (16)$$

Inequality (16) with consideration of (13) while $\theta_k = \theta^0 + \varepsilon\left(0 < \varepsilon \le \theta_k^0\right)$ could be rewritten as follows:

$$-\varepsilon\left|\mathbf{s}_f(X)-\mathbf{s}_{h_k}(X)\right|^2 > 0.$$

It follows from the last inequality that $\mathbf{s}_{h_{k+1}}(X) \neq \mathbf{s}_{h_k}(X)$, if $\theta \in \left(\theta_k^0, 2\theta_k^0\right]$. However, this does not mean that there are no such different natural numbers r and k, for which the following equality is true:

$$\mathbf{s}_{h_r}(X) = \mathbf{s}_{h_k}(X). \quad (17)$$

If equality (17) is true, then they say that in region of characteristic vectors of Boolean function h_j relating to system of characters X the limit cycle has formed.

Let k — is such smallest natural number, that $k > r$, and equality (17) is true. Lets consider the system of vectors $\mathbf{s}_f(X)-\mathbf{s}_{h_r}, \mathbf{s}_f(X)-\mathbf{s}_{h_{r+1}}(X), \ldots, \mathbf{s}_f(X)-\mathbf{s}_{h_{k-1}}(X)$ and their linear combination:

$$\sum_{i=0}^{k-r-1}\lambda_i\left(\mathbf{s}_f(X)-\mathbf{s}_{h_{r+i}}(X)\right), \quad (18)$$

with not negative coefficients $\lambda_i \ge 0$ $(i = 0,1,\ldots,k-r-1)$. If among coefficients λ_i at least one of them does not equal to zero and linear combination (18) equals to zero, then function f is not implemented by one NE relating to system of characters X. Indeed, when assuming the opposite, then function f is implemented by one NE relating to system X with vector of structure $\mathbf{w}$ and following equality is true:

$$\sum_{i=0}^{k-r-1}\lambda_i\left(\mathbf{s}_f(X)-\mathbf{s}_{h_{r+i}}(X)\right) = 0, \quad (19)$$

at least with one nonzero value of λ_i. Then, having scalarly multiplied the left and right parts (19) on $\mathbf{w}$, we will receive:

$$\sum_{i=0}^{k-r-1}\lambda_i\left(\left(\mathbf{s}_f(X), \mathbf{w}\right)-\left(\mathbf{s}_{h_{r+i}}(X), \mathbf{w}\right)\right) = 0,$$

that contradicts the inequality (5).

Therefore, when in area of characteristic vectors of functions h_j relating to system of characters X, the limit cycle has formed and (19) is true at least with one value of λ_i $(\lambda_i > 0)$, then we can make the conclusion that function f is not implemented by one NE relating to system of characters X.

Algorithm of synthesis of NE relating to system of characters X by method of iteration.

Step 1. Lets find characteristic vector $\mathbf{s}_f(X)$ of Boolean function $f(x_1, \ldots, x_n)$, which is given in alphabet $\{-1,1\}$ relating to system of characters X, we perform assignment: $\mathbf{v}_1 = \mathbf{s}_f(X)$, $k = 1$ and move to step 2.

Step 2. If $\forall \mathbf{g} \in G_n \quad \mathbf{v}_k(\mathbf{g}) \neq 0$, then we will determine the function:

$$h_k(\mathbf{g}) = \mathrm{Rsign}\mathbf{v}_k(\mathbf{g}),$$

and move to step 3, while in the opposite case we move to step 6.

Step 3. If $f(\mathbf{g}) = h_k(\mathbf{g})$ for all $\mathbf{g} \in G_n$, then function f is implemented on NE with vector of structure $\mathbf{w} = \mathbf{v}_k$ and process of synthesis of NE is completed, in the opposite case we move to step 4.

Step 4. We search for characteristic vector $\mathbf{s}_{h_k}$ of function h_k relating to system X and check if there is such number $r < k$, so that $\mathbf{s}_{h_r} = \mathbf{s}_{h_k}$. If such number r exists, then we move to step 7, in the opposite case we move to step 5.

Step 5. We find vector $\mathbf{v}_{k+1}$ according to formula:

$$\mathbf{v}_{k+1} = \mathbf{v}_k + \theta_k\left(\mathbf{s}_f(X)-\mathbf{s}_{h_k}(X)\right),$$

where $\theta_k \in \left(\theta_k^0, 2\theta_k^0\right]$. We perform assignment $k = k+1$ and move to step 2.

Step 6. If $k = 1$, then we change the coordinates of vector $\mathbf{v}_k$ in random manner, so that:

$$\forall \mathbf{g} \in G_n \quad \mathbf{v}_k(\mathbf{g}) \neq 0, \quad (20)$$

and move to step 2.

If $k \neq 1$, then we will choose such $\theta_k \in \left(\theta_k^0, 2\theta_k^0\right]$ for which the inequality (20) is fulfilled and we move to step 5.

Step 7. In area of characteristic vectors of Boolean functions $h_1, h_2, \ldots, h_k$ relating to system X, the limit cycle was formed, that is: $\mathbf{s}_{h_r}(X) = \mathbf{s}_{h_k}(X)$ $(r < k)$. If we could choose such $\lambda_i \ge 0$, where not all λ_i equal to zero and for which the equality $\sum_{i=0}^{k-r-1}\lambda_i\left(\mathbf{s}_f(X)-\mathbf{s}_{h_{r+i}}(X)\right) = 0$ is true, then function f could not be implemented by one NE relating to system X. In the opposite case we move to step 5. Lets consider the iteration method of synthesis of generalized NE with following examples.

Example 1. Let consider Boolean function $f(x_1, \ldots, x_n)$ in alphabet $\{-1,1\}$, which takes the value 1 on the sets (1,1,-1), (1,-1,1), (-1,1,1). Group of characters $X(G_3) = \{\chi_0, \chi_1, \ldots, \chi_7\}$, function f and its spectrum $\mathbf{s}_f$ with accuracy to multiplier 2^3 we will present in Table 1.

Table 1. Group of characters $X(G_3)$ and spectrum $\mathbf{s}_f$

G_3	x_1	x_2	x_3	χ_0	χ_1	χ_2	χ_3	χ_4	χ_5	χ_6	χ_7	f	$\mathbf{s}_f$
$\mathbf{g}_0$	1	1	1	1	1	1	1	1	1	1	1	-1	-2
$\mathbf{g}_1$	1	1	-1	1	-1	1	-1	1	-1	1	-1	1	2
$\mathbf{g}_2$	1	-1	1	1	1	-1	-1	1	1	-1	-1	1	2
$\mathbf{g}_3$	1	-1	-1	1	-1	-1	1	1	-1	-1	1	-1	-2
$\mathbf{g}_4$	-1	1	1	1	1	1	1	-1	-1	-1	-1	1	2
$\mathbf{g}_5$	-1	1	-1	1	-1	1	-1	-1	1	-1	1	-1	-2
$\mathbf{g}_6$	-1	-1	1	1	1	-1	-1	-1	-1	1	1	-1	-2
$\mathbf{g}_7$	-1	-1	-1	1	-1	-1	1	-1	1	1	-1	-1	-6

If we switch from alphabet $\{-1,1\}$ to alphabet $\{0,1\}$ according to the rule $-1\to 1$ and $1\to 0$ $\left(y_i=\frac{1}{2}(1-x_i);\ x_i\in\{-1,1\}\right)$, then kernel $K(f)=f^{-1}(0)=\{(0,0,1),(0,1,0),(1,0,0)\}$. It is obvious that none of consolidated kernels $K(f)_i$ [29] from which elements we will build the matrixes

$$K(f)_1=\begin{pmatrix}0&0&0\\0&1&1\\1&0&1\end{pmatrix},$$

$$K(f)_2=\begin{pmatrix}0&1&1\\0&0&0\\1&1&0\end{pmatrix},$$

$$K(f)_3=\begin{pmatrix}1&0&1\\1&1&0\\0&0&0\end{pmatrix}$$

does not allow representation with matrixes of tolerance with E_3^-. Consequently, function f is not implemented by one NE relating to variables x_1,x_2,x_3.

According to iteration algorithm of synthesis of generalized NE, we should check the implementation of function f relating to system $\chi=\{\chi_7\}$ (character χ_7— corresponds to the maximum by modulus spectral coefficient s_7). According to algorithm $\mathbf{v}_1=(-6;-2)$. For all $\mathbf{g}\in G_3$ $\mathbf{v}_1(\mathbf{g})=-6\chi_7(\mathbf{g})-2\neq 0$ and we should build the function $h_1(\mathbf{g})=\mathrm{Rsign}\mathbf{v}_1(\mathbf{g})$. Function $h_1(\mathbf{g}_7)=1$, while $f(\mathbf{g}_7)=-1$, that is $f\neq h_1$. We find $\mathbf{s}_{h_1}(\chi)$: $\mathbf{s}_{h_1}(\chi)=(-8;0)$. Lets calculate θ_1^0 according to formula (13): $\theta_1^0=1$. Then:

$$\mathbf{v}_2(\mathbf{g})=\mathbf{v}_1+\theta_1(\mathbf{s}_f(\chi)-\mathbf{s}_{h_1}(\chi)),$$

where $\theta_1\in(1,2]$. Let $\theta_1=2$. In this case $\mathbf{v}_2=(-2:-6)$. For all $\mathbf{g}\in G_3$ $\mathbf{v}_2(\mathbf{g})\neq 0$ and we build function $h_2(\mathbf{g})=\mathrm{Rsign}\mathbf{v}_2(\mathbf{g})$. Function h_2 does not coincide with function f on sets $\mathbf{g}_1,\mathbf{g}_2,\mathbf{g}_3$. Lets find characteristic vector $\mathbf{s}_{h_2}(\chi)=(0;-8)$, $\theta_2^0=\frac{1}{3}$ and

$$\mathbf{v}_3(\mathbf{g})=\mathbf{v}_2+\theta_2(\mathbf{s}_f(\chi)-\mathbf{s}_{h_2}(\chi)),$$

where: $\theta_2\in\left(\frac{1}{2},\frac{2}{3}\right]$. Let $\theta_2=\frac{2}{3}$. Then $\mathbf{v}_3=(-6:-2)$. On each element $\mathbf{g}$ of group G_3 $\mathbf{v}_3(\mathbf{g})\neq 0$ and $h_3(\mathbf{g})=\mathrm{Rsign}\mathbf{v}_3(\mathbf{g})$. Lets find $\mathbf{s}_{h_3}(\chi)=(-8;0)$. In area of characteristic vectors of Boolean function h_1,h_2,h_3 relating to system χ the limit cycle has formed: $\mathbf{s}_{h_1}(\chi)=\mathbf{s}_{h_3}(\chi)$. According to the algorithm we move to step 7 and build vectors $\mathbf{s}_f(\chi)-\mathbf{s}_{h_1}(\chi)=(2;-2)$, $\mathbf{s}_f(\chi)-\mathbf{s}_{h_2}(\chi)=(-6;6)$. If $\lambda_0=3\cdot$ and $\lambda_1=1$, it becomes obvious that the following equality is true

$$\lambda_0(\mathbf{s}_f(\chi)-\mathbf{s}_{h_1}(\chi))+\lambda_1(\mathbf{s}_f(\chi)-\mathbf{s}_{h_2}(\chi))=0.$$

It means that function f is not implemented by one generalized NE relating to system $\chi=\{\chi_7\}$.

Example.2. Let f is Boolean function that was considered in previous example. For system of characters χ of generalized NE lets choose $\{\chi_5,\chi_6,\chi_7\}$.

Then $\mathbf{s}_f(\chi)=(-2,-2,-6;-2)$. On element $\mathbf{g}_7=(1,1,-1)$ function $\mathbf{v}_1(\mathbf{g})$ takes the value 0. According to algorithm we can change vector $\mathbf{v}_1=(-2,-2,-6;-2)$ in arbitrary manner, because $k=1$.

Lets increase the last coordinate v_0 of vector $\mathbf{v}_1$ by 1: $\mathbf{v}_1=(-2,-2,-6;-1)$. After such modification of vector $\mathbf{v}_1$ we can see that $\mathbf{v}_1(\mathbf{g})\neq 0$ for all $\mathbf{g}\in G_3$. Lets build the function $h_1(\mathbf{g})=\mathrm{Rsign}\mathbf{v}_1(\mathbf{g})$, we find that $\mathbf{s}_{h_1}(\chi)=(0,0,-8;0)$, $\theta_1^0=\frac{1}{8}$ and

$$\mathbf{v}_2(\mathbf{g})=\mathbf{v}_1+\theta_1(\mathbf{s}_f(\chi)-\mathbf{s}_{h_1}(\chi)),$$

$\theta_1\in\left(\frac{1}{8},\frac{1}{4}\right]$. Let $\theta_1=\frac{1}{4}$. Then $\mathbf{v}_2=(-2,-2,-6;-1)+$ $+\frac{1}{4}(-2,-2,2;-2)=\left(-\frac{5}{2},-\frac{5}{2},-\frac{11}{2};-\frac{3}{2}\right)$. For all $\mathbf{g}\in G_3$. $\mathbf{v}_2(\mathbf{g})\neq 0$ and $h_2(\mathbf{g})=\mathrm{Rsign}\mathbf{v}_2(\mathbf{g})$. Functions f and h_2 coincide. This means that function $f(x_1,\ldots,x_n)$ is implemented by one generalized NE relating to system of characters $\chi=\{\chi_5,\chi_6,\chi_7\}$ with vector of structure $\mathbf{w}=2\mathbf{v}_2=(-5,-5,-11;-3)$. Consequently, $\forall\mathbf{g}\in G_3$ $f(\mathbf{g})=\mathrm{Rsign}(-5\chi_5(\mathbf{g})-5\chi_6(\mathbf{g})-11\chi_7(\mathbf{g})-3)$.

CONCLUSIONS

In present work author has developed the effective method of synthesis of NE with generalized threshold activation function that could be successfully applied at construction of forecasting and recognition schemes in neural basis. Author has received the sufficient condition of unrealization of logics algebra functions by one NE relating to arbitrary system of characters of their definition areas over the field of real numbers.

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The logic and linguistic model for automatic extraction of collocation similarity

N. Khairova[1], S. Petrasova[2], Ajit Pratap Singh Gautam[3]

National Technical University "Kharkiv Polytechnic Institute"; e-mail: nina_khajrova@yahoo.com

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Abstract. The article discusses the process of automatic identification of collocation similarity. The semantic analysis is one of the most advanced as well as the most difficult NLP task. The main problem of semantic processing is the determination of polysemy and synonymy of linguistic units. In addition, the task becomes complicated in case of word collocations. The paper suggests a logical and linguistic model for automatic determining semantic similarity between colocations in Ukraine and English languages. The proposed model formalizes semantic equivalence of collocations by means of semantic and grammatical characteristics of collocates. The basic idea of this approach is that morphological, syntactic and semantic characteristics of lexical units are to be taken into account for the identification of collocation similarity. Basic mathematical means of our model are logical-algebraic equations of the finite predicates algebra. Verb-noun and noun-adjective collocations in Ukrainian and English languages consist of words belonged to main parts of speech. These collocations are examined in the model. The model allows extracting semantically equivalent collocations from semi-structured and non-structured texts. Implementations of the model will allow to automatically recognize semantically equivalent collocations. Usage of the model allows increasing the effectiveness of natural language processing tasks such as information extraction, ontology generation, sentiment analysis and some others.

Key words: automatic extraction, identification of collocation similarity, finite predicates algebra, logical-algebraic equations, grammatical and semantic features.

INTRODUCTION

This is a particularly exciting time to be working on computer linguistic or natural language processing. Nowadays linguistic technologies have become not only tools for modelling language but also a production factor. Computer linguistics is now one of the most strongly developing directions of information technologies. In fact, almost every intelligent information system with a user interface, both text and web-content processing systems, uses linguistic technologies [1].

The vast amount of textual data on the Web and social media has made it possible to build lots of new and interesting applications.

Important tasks of computer linguistic include: Information extraction (IE), Sentiment analysis, Machine translation, Information retrieval, Ontology generation and some others.

One important task of natural language processing is information extraction. IE is the task of automatically extracting structured information from unstructured and/or semi-structured textual information. In fact, the task of IE is to identify instances of a particular prespecified class of entities, relationships and events in natural language texts, and the extraction of the relevant properties of the identified entities, relationships or events [2].

Another application of this kind of IE, involves sentiment analysis. Sentiment analysis (also known as opinion mining) refers to the use of NLP to identify and extract subjective information in texts. This can be used for lot of tasks [3]. For example:

- such information can become an additional powerful source for predicting the expected stock market changes;
- such information can become a source to predict election outcomes;
- such information can help a corporation to determine what people think about some (new) products;
- such information can help politics to determine what people think about candidates or issues;
- and many others tasks.

Another task of computer linguistics that is very important nowadays is ontology generation [4]. Ontology generation (aka ontology acquisition) is the automatic or semi-automatic creation of ontologies, including extracting the corresponding domain's terms and the relationships between those concepts from a corpus of natural language text [5]. This task typically involves:

- technology for automated concepts extraction using linguistic processor [6]
- and extraction of the semantic relations between concepts using linguistic processor.

Another modern application of NLP is to identify text clones, for example, in the technical documentation [7]. A text clone means a block of text that is repeated in various degrees of similarity across the documentation [8].

A number of things make natural language understanding difficult. These are problems with ambiguity, idioms, segmentation of words and sentences, non-standard language that we frequently see in texts of

Twitter, SMS, blog, social media and others. And of course we also have a lot of problems with entity names, synonymy and co-reference.

The above-mentioned problems include challenge of collocation extraction and semantic equivalence recognition. Solving this problem applied to tasks of Automatically Ontology Generation, Sentiment Analysis and Information Extraction is still quite hard.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The notion of a collocation differs across linguistic traditions. For instance, a collocation is a recurrent word combination [9]. By contrast, a collocation is a word combination whose semantic and/or syntactic properties cannot be fully predicted from those of its components [10].

In this study, a collocation is considered as a combination of two lexical units that co-occur in the text non-randomly. The available variety of collocations extraction methods can be divided into two groups.

The methods from the first group are statistical methods. Statistical measures have become extremely widespread in modern linguistic research. These measures are based on co-occurrence frequencies of word pairs and frequencies of each constituent [11].

The *window-based methods* rely on a linear word order model, in which the collocation candidates are extracted from a fixed-size window [12].

Mutual information (*MI*) and *Pointwise mutual information* (*PMI*) measures are used to determine the significance of the occurrence of two words by comparing the frequency of their co-occurrence with the product of frequencies of their independent occurrence in the text [13].

The *T-score measure* takes into account the frequency of co-occurrence of a keyword and its collocate. Words with the highest T-score occur frequently, so we must set a list of stop words to reject the most frequent words.

The *Chi-squared distribution* uses the Pearson $\chi 2$-test to evaluate how likely it is that any observed difference between the sets arose by chance. The four values of a contingency table are:

- frequency of a collocation;
- frequency of a collocation with the first word (without the second one);
- frequency of a collocation with the second word (without the first one);
- frequency of all other collocations.

The drawbacks of statistical methods are extraction of noise and ignoring of syntactic correlations between words in long distances.

The methods from the second group are based on the analysis of the syntactic structure of collocations [14]. The analysis of the syntactic structure allows to filter out false collocates as well as to extract collocates located in a long distance from each other. It should be noted that this extended precision is achieved by a careful description of all possible syntactic constructions for two collocates.

It is also worth noting that methods of collocation extraction have become widely used in modern corpus linguistics [15].

Far fewer studies are aimed at solving the identification of collocation similarity problem [16, 17, 18].

OBJECTIVES

In the article we are focusing on the problems of collocation extraction and semantic equivalence recognition. Semantic equivalents can be defined as words with a similar meaning. The main aim is detecting that two collocations mean the same thing or the identification of collocation similarity.

Two-word phrases formed by pairs of semantic equivalents may be semantically similar (Fig.1)

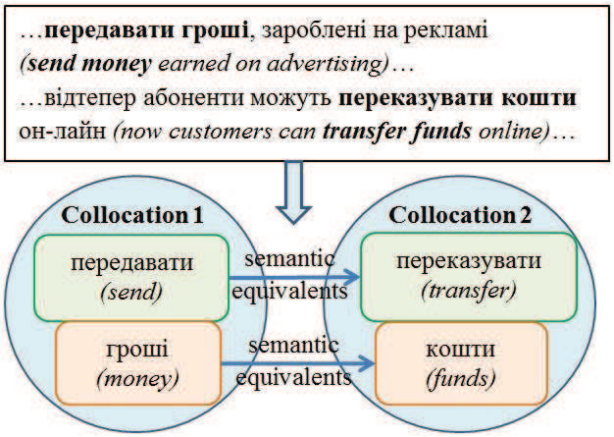

Fig. 1. Collocation similarity.

Collocations may be semantically dissimilar, even if they are collocates, which are equivalents (Fig.2).

The proposed logical-linguistic model formalizes semantic equivalence of collocations by means of semantic and grammatical characteristics of the collocates. The basic idea of this approach is that there is common content (meaning) between collocates that have semantic correlations. And this meaning expresses similarity of denoted concepts or phenomena. We consider verb-noun and noun-adjective collocations in Ukrainian and English languages. To formally express Collocation Similarity we use logical-algebraic equations of the finite predicates algebra.

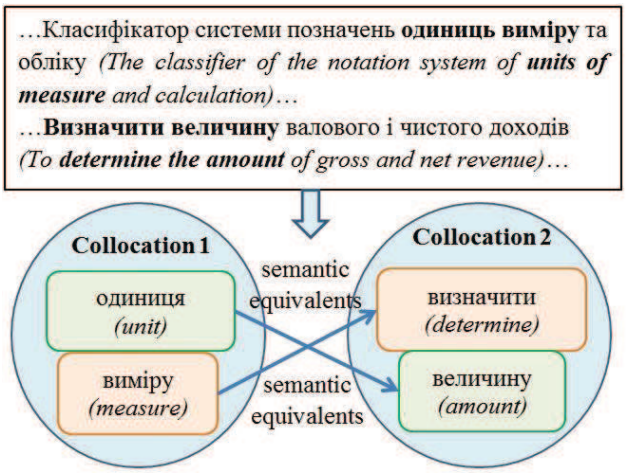

Fig.2. Collocation dissimilarity.

BASIC MEANS OF THE MODEL

Basic mathematical means of our model are logical-algebraic equations of the finite predicates algebra [19]. Let U be a universe of elements. The universe U contains various elements of the language system: lexemes, sentences, phrases, word-combinations, words etc. The universe is finite, as the sets of the elements are finite and determinate. The set $M = \{m_1, \dots, m_n\}$ is a subset of grammatical and semantic features of a collocate, and n is amount of system features. Predicates P_i are defined over the Cartesian products $M_1 \times M_2 \times \dots \times M_n$. They designate relations between grammatical and semantic features of collocates by formal tool of the finite predicates algebra [20]. Predicate $P(x) = 1$, if the main word features of the collocation have a certain grammatical and semantic characteristics. Predicate $P(y) = 1$, if the dependent word features of the collocation have a certain grammatical and semantic characteristics. And both predicates equal zero otherwise.

Variables $x_1, x_2, \dots, x_n$ are called subject variables and their values are called subjects. The recognition predicate of the subject a by the subject variable x_i is the basic one for the algebra of predicates:

$$x_i^a = \begin{cases} 1, \text{if } x_i = a \\ 0, \text{if } x_i \neq a \end{cases} (1 \le i \le n), \tag{1}$$

where $i = \{1,2, \dots, n\}$, a is any of the universe elements.

MODELING OF COLLOCATION SIMILARITY IDENTIFICATION IN UKRAINIAN LANGUAGE

We can define a set of grammatical and semantic characteristics of collocates for Ukrainian language using two subject variables (1). The variable a defines grammatical categories of Ukrainian language:

$$a^{NNom} \vee a^{NGen} \vee a^{NAcc} \vee a^{NDat} \vee a^{NIn} \vee a^{NPr} \vee a^{ANom} \vee \vee a^{AGen} \vee a^{AAcc} \vee a^{ADat} \vee a^{AIn} \vee a^{APr} \vee a^{VRef} \vee a^{VNonRef} = 1,$$

where: a^{NNom} is a noun, nominative case; a^{NGen} is a noun, genitive case; $a^{N\,Pr}$ is a noun, prepositional case; a^{ANom} is an adjective, nominative case; a^{AAcc} is an adjective, accusative case, a^{ADat} is an adjective, dative case; a^{VRef} is a verb, reflexive; $a^{VNonRef}$ is a verb, non-reflexive.

The subject variable c defines semantic categories:

$$c^{Ag} \vee c^{Att} \vee c^{Pac} \vee c^{Adr} \vee c^{Ins} \vee c^{M} = 1,$$

where: c^{Ag} – an agent, c^{Att} – an attribute, c^{Pac} – an patient, c^{Adr} – an addressee, c^{Ins} – an instrument, c^{M} – a location or content.

As we mentioned above predicate $P(x)$ defines grammatical and semantic characteristics of the main word of collocations:

$$P(x) = a_x^{NNom} c_x^{AG} \vee a_x^{NGen} c_x^{Att} \vee a_x^{NAcc} c_x^{Pac} \vee \vee a_x^{NDat} c_x^{Adr} \vee a_x^{NIn} c_x^{Ins} \vee a_x^{NPr} c_x^{M} \vee a_x^{VNonRef}. \tag{2}$$

Whereas predicate $P(y)$ defines grammatical and semantic characteristics of the dependent word of collocations:

$$P(y) = a_y^{NGen} c_y^{Att} \vee a_y^{NAcc} c_y^{Pac} \vee a_y^{NDat} c_y^{Adr} \vee \vee a_y^{NIn} c_y^{Ins} \vee a_y^{NPr} c_y^{M} \vee a_y^{ANom} \vee a_y^{AGen} \vee \vee a_y^{AAcc} \vee a_y^{ADat} \vee a_y^{AIn} \vee a_y^{APr}. \tag{3}$$

Double predicate $P(x, y)$ describes a combination of semantic and grammatical information of words in two-word collocations:

$$P(x, y) = (a_y^{ANom} \vee a_y^{AGen} \vee a_y^{AAcc} \vee a_y^{ADat} \vee \vee a_y^{AIn} \vee a_y^{APr}) (a_x^{NNom} c_x^{AG} \vee a_x^{NGen} c_x^{Att} \vee \vee a_x^{NAcc} c_x^{Pac} \vee a_x^{NDat} c_x^{Adr} \vee a_x^{NIn} c_x^{Ins} \vee a_x^{NPr} c_x^{M}) \vee \vee a_x^{VNonRef} a_y^{NAcc} c_y^{Pac} \vee a_x^{NNom} c_x^{Ag} a_y^{NGen} c_y^{Att}. \tag{4}$$

The predicate equals unity, if the both words that have a certain grammatical and semantic features form a collocation. And predicate equal zero otherwise. For example, the last conjunction of the predicate describes the semantic and grammatical characteristics of the following collocations:

- *мова* $a_x^{NNom} c_x^{Ag}$ *розмітки* $a_y^{NGen} c_y^{Att}$ *(a markup language)*;
- *період* $a_x^{NNom} c_x^{Ag}$ *користування* $a_y^{NGen} c_y^{Att}$ *(a usage period)*.

A predicate of semantic equivalence can be defined between collocations. The ratio of semantic equivalence of two two-word collocations can be defined as:

$$P(x_1, y_1) * P(x_2, y_2) = = \gamma_i (x_1, y_1, x_2, y_2) \bullet P(x_1, y_1) \bullet P(x_2, y_2), \tag{5}$$

where: * indicates semantic similarity, • defines the Cartesian product, $\gamma_i(x_1, y_1, x_2, y_2)$ predicate eliminates collocations between which semantic equivalence cannot be identified.

For example predicate γ_1 defines the semantic similarity between the collocations:

"to store data" and *to "keep indicators"*

The predicate γ_2:

$$\gamma_1(x_1, y_1, x_2, y_2)= = a_{x1}{}^{\text{VNonRef}} a_{y1}{}^{\text{NAcc}} c_{y1}{}^{\text{Pac}} a_{x2}{}^{\text{VNonRef}} a_{y2}{}^{\text{NAcc}} c_{y2}{}^{\text{Pac}}$$

shows, for example, the semantic similarity between the following collocations:

"*набір приладдя*" *(a tool set)* and "*комплект устаткування*" *(an equipment package)*. The predicate γ_3:

$$\gamma_2(x_1, y_1, x_2,y_2)= = a_{x1}{}^{\text{NNom}} c_{x1}{}^{\text{Ag}} a_{y1}{}^{\text{NGen}} c_{y1}{}^{\text{Att}} a_{x2}{}^{\text{NNom}} c_{x2}{}^{\text{Ag}} a_{y2}{}^{\text{NGen}} c_{y2}{}^{\text{Att}}$$

shows, for example, the semantic similarity between the following collocations:

"*грошовий переказ*" *(a money transfer)* and "*відправлення коштів*" *(a transmission of funds)*.

$$\gamma_3(x_1, y_1, x_2, y_2)= = a_{y1}{}^{\text{ANom}} a_{x1}{}^{\text{NNom}} c_{x1}{}^{\text{Ag}} a_{x2}{}^{\text{NNom}} c_{x2}{}^{\text{Ag}} a_{y2}{}^{\text{NGen}} c_{y2}{}^{\text{Att}}$$

Further, to rationalize the equation, we will take into account only a normalized form for adjectives.

Thus, a predicate of semantic equivalence between collocations consisted of semantically equivalent pairs of collocates can be defined as:

$$\begin{aligned}\gamma(x_1, y_1, x_2, y_2) = {} & a_{y1}{}^{\text{ANom}} a_{x1}{}^{\text{NNom}} c_{x1}{}^{\text{Ag}} a_{y2}{}^{\text{ANom}} a_{x2}{}^{\text{NNom}} c_{x2}{}^{\text{Ag}} \vee (a_{x1}{}^{\text{NNom}} c_{x1}{}^{\text{Ag}} \vee a_{x1}{}^{\text{NGen}} c_{x1}{}^{\text{Att}} \vee a_{x1}{}^{\text{NAcc}} c_{x1}{}^{\text{Pac}} \vee \\ \vee a_{x1}{}^{\text{NDat}} c_{x1}{}^{\text{Adr}} \vee a_{x1}{}^{\text{NIn}} c_{x1}{}^{\text{Ins}} \vee a_{x1}{}^{\text{NPrt}} c_{x1}{}^{\text{M}}) a_{y1}{}^{\text{NGen}} c_{y1}{}^{\text{Att}} (a_{x2}{}^{\text{NNom}} c_{x2}{}^{\text{Ag}} \vee a_{x2}{}^{\text{NGen}} c_{x2}{}^{\text{Att}} \vee a_{x2}{}^{\text{NAcc}} c_{x2}{}^{\text{Pac}} \vee a_{x2}{}^{\text{NDat}} c_{x2}{}^{\text{Adr}} \vee \\ \vee a_{x2}{}^{\text{NIn}} c_{x2}{}^{\text{Ins}} \vee a_{x2}{}^{\text{NPrt}} c_{x2}{}^{\text{M}}) a_{y2}{}^{\text{NGen}} c_{y2}{}^{\text{Att}} \vee a_{x1}{}^{\text{VNonRef}} a_{y1}{}^{\text{NAcc}} c_{y1}{}^{\text{Pac}} a_{x2}{}^{\text{VNonRef}} a_{y2}{}^{\text{NAcc}} c_{y2}{}^{\text{Pac}}\end{aligned} \quad (6)$$

The predicate equals unity, if certain grammatical and semantic characteristics of the collocations words satisfy the given equation. In this case two collocations are semantically equivalent or they have similar meaning.

Examples of collocation similarity.

- Verb collocations:

"*визначати відомості*" *(to define information)* ≈ ≈"*встановлювати дані*" *(to identify data)*.

- Nominal collocations:
  - substantive collocations:

"процес утворення" (the process of establishing) ≈ ≈ *"хід формування" (the course of formation)* ≈ ≈ *"процедура заснування" (the procedure of foundation)*;

  - adjective collocations:

"*інформаційний потік" (a data flow)* ≈ *"кількість інформації" (an amount of information).*

Predicate equals zero when two collocations are semantically dissimilar.

SEMANTIC EQUIVALENCE BETWEEN ENGLISH COLLOCATIONS

We can define a set of grammatical and semantic characteristics of English collocates using two subject variables as well as Ukrainian collocates.

This research deals with semantic equivalence between collocates which consist of words belonged to main parts of speech. The study of main parts of speech in combination with auxiliary ones (e.g. prepositions, conjunctions etc.) goes beyond the scope of this research. The only exception is the preposition *"of"* as it identifies main and dependent words in a '*noun-noun'* (NN) collocation.

The subject variables *a* defines grammatical characteristics in the English language:

$$a^{\text{NSub}} \vee a^{\text{NObj}} \vee a^{\text{NSubOf}} \vee a^{\text{NObjOf}} \vee a^{\text{VTr}} \vee \vee a^{\text{VIntr}} \vee a^{\text{AAtt}} \vee a^{\text{APr}} = 1,$$

where: a^{NSub} is a noun, subject, a^{NSubOf} is a noun, subject, with the preposition "*of*", a^{NObj} is a noun, object, a^{NObjOf} is a noun, object, with the preposition "*of*"; a^{AAtt} is an adjective, attribute, a^{APr} is an adjective, predicative; a^{VTr} is a verb, transitive, a^{VIntr} is a verb, intransitive.

The subject variable *c* defines semantic categories, which are similar to described in equation 2.

$$c^{Ag} \vee c^{Att} \vee c^{Pac} \vee c^{Adr} \vee c^{Ins} \vee c^{M} = 1,$$

where: c^{Ag} – an agent, c^{Att} – an attribute, c^{Pac} – an patient, c^{Adr} – an addressee, c^{Ins} – an instrument, c^{M} –a location or content.

The *P(x)* predicate introduced on the set of word *M* equals unity ($P(x) = 1$), if the main word (collocate) of collocations has a certain grammatical and semantic information:

$$\begin{aligned}P(x)= {} & a_x{}^{\text{NSub}} c_x{}^{\text{Ag}} \vee a_x{}^{\text{NObj}} c_x{}^{\text{Att}} \vee a_x{}^{\text{NObj}} c_x{}^{\text{Pac}} \vee a_x{}^{\text{NObj}} \vee \\ & \vee c_x{}^{\text{Adr}} \vee a_x{}^{\text{NObj}} c_x{}^{\text{Ins}} \vee a_x{}^{\text{NObj}} c_x{}^{\text{M}} \vee a_x{}^{\text{NSubOfj}} c_x{}^{\text{Ag}} \vee \\ & \vee a_x{}^{\text{NObjOf}} c_x{}^{\text{Att}} \vee a_x{}^{\text{NObjOf}} c_x{}^{\text{Pac}} \vee a_x{}^{\text{NObjOf}} c_x{}^{\text{Adr}} \vee \\ & \vee a_x{}^{\text{NObjOf}} c_x{}^{\text{Ins}} \vee a_x{}^{\text{NObjOf}} c_x{}^{\text{M}} \vee a_x{}^{\text{VT}}.\end{aligned} \quad (7)$$

The set of semantic and grammatical characteristics of the dependent word (collocate) of collocations is described by predicate *P*(*y*):

$$\begin{aligned}P(y) = {} & a_y{}^{\text{NObj}} c_y{}^{\text{Att}} \vee a_y{}^{\text{NObj}} c_y{}^{\text{Pac}} \vee a_y{}^{\text{NObj}} c_y{}^{\text{Adr}} \vee \\ & \vee a_y{}^{\text{NObj}} c_y{}^{\text{Ins}} \vee a_y{}^{\text{NObj}} c_y{}^{\text{M}} \vee a_y{}^{\text{VTr}} \vee a_y{}^{\text{VIntr}} \vee a_y{}^{\text{AAtt}} \vee \\ & \vee a_y{}^{\text{Apr}}.\end{aligned} \quad (8)$$

Double predicate $P(x, y)$ describes a binary relation which is a subset of the Cartesian product of $P(x) \bullet P(y)$. This relation determines a combination of semantic and grammatical information about word forms of two-word collocations:

$$\begin{aligned}P(x, y) = {} & ((a_x{}^{\text{NSub}} \vee a_x{}^{\text{NSubOf}}) c_x{}^{\text{Ag}} \vee a_x{}^{\text{VTr}})(a_y{}^{\text{NObj}} (c_y{}^{\text{Att}} \vee \\ & \vee c_y{}^{\text{Pac}}) \vee a_y{}^{\text{VTr}} \vee a_y{}^{\text{VIntr}} \vee a_y{}^{\text{AAtt}} \vee a_y{}^{\text{APr}}).\end{aligned} \quad (9)$$

A predicate of semantic equivalence can be defined between collocations in English language. The ratio of

semantic equivalence of two two-word collocations can

"*a wireless device*" ≈"*a cordless machine*" ≈"*a device is wireless*"; "*a standard is created* "≈ "*the criterion is formed"*. (11)

Predicate γ_2:

$$\gamma_2(x_1, y_1, x_2, y_2) = a_{x1}{}^{NSubOf} c_{x1}{}^{Ag} a_{y1}{}^{NObj} c_{y1}{}^{Att} \vee \vee a_{x2}{}^{NObj} c_{x2}{}^{Att} a_{y2}{}^{NSub} c_{y2}{}^{Ag}$$

be defined as equation (5). The predicate γ_i eliminates collocations between which semantic equivalence cannot be identified in the equation.

In English, collocations γ_i can be identified as:

$$\gamma_1(x_1, y_1, x_2, y_2) = = a_{y1}{}^{AAtt} a_{x1}{}^{NSub} c_{x1}{}^{Ag} \vee a_{x2}{}^{NSub} c_{x2}{}^{Ag} a_{y2}{}^{APr}. \quad (10)$$

Predicate γ_1 shows, for example, the semantic similarity between the following collocations:
shows, for example, the semantic similarity between the following collocations:

the usage of data ≈ the application of information ≈ ≈ the data usage;
a content provider ≈ a maintenance supplier.

Predicate γ_3:

$$\gamma_3(x_1, y_1, x_2, y_2) = = a_{x1}{}^{NSub} c_{x1}{}^{Ag} a_{y1}{}^{VTt} \vee a_{x2}{}^{NSub} c_{x2}{}^{Ag} a_{y2}{}^{VIntr} \quad (12)$$

shows the semantic similarity between the following collocations:

an equipment detects ≈ an appliance finds;
broadcast happened ≈ transmission occurred.

Predicate γ_4:

$$\gamma_4(x_1, y_1, x_2, y_2) = = a_{x1}{}^{VTt} a_{y1}{}^{NObj} c_{y1}{}^{Pac} \vee a_{x2}{}^{VTt} a_{y2}{}^{NObj} c_{y2}{}^{Pac} \quad (13)$$

shows the semantic similarity between the collocations:

provide aid ≈ give support.

Thus, a predicate of semantic equivalence between collocations consisted of semantically equivalent pairs of collocates in the English language can be defined as:

$$\begin{aligned}\gamma(x_1,y_1,x_2,y_2) = & = (a_{y1}{}^{AAtt} a_{x1}{}^{NSub} c_{x1}{}^{Ag} \vee a_{x1}{}^{NSub} c_{x1}{}^{Ag} a_{y1}{}^{APr}) \cdot \\ & \cdot (a_{y2}{}^{AAtt} a_{x2}{}^{NSub} c_{x2}{}^{Ag} \vee a_{x2}{}^{NSub} c_{x2}{}^{Ag} a_{y2}{}^{APr}) \vee \\ & \vee (a_{x1}{}^{NSubOf} c_{x1}{}^{Ag} a_{y1}{}^{NObj} c_{y1}{}^{Att} \vee \\ & \vee a_{x1}{}^{NObj} c_{x1}{}^{Att} a_{y1}{}^{NSub} c_{y1}{}^{Ag}) (a_{x2}{}^{NSubOf} c_{x2}{}^{Ag} \cdot \\ & \cdot a_{y2}{}^{NObj} c_{y2}{}^{Att} \vee a_{x1}{}^{NObj} c_{x2}{}^{Att} a_{y2}{}^{NSub} c_{y2}{}^{Ag}) \vee \\ & \vee a_{x1}{}^{NSub} c_{x1}{}^{Ag} (a_{y1}{}^{VTt} \vee a_{y1}{}^{VIntr}) \vee \\ & \vee a_{x2}{}^{NSub} c_{x2}{}^{Ag} (a_{y2}{}^{VTt} \vee a_{y2}{}^{VIntr}) \vee \\ & \vee a_{x1}{}^{VTt} a_{y1}{}^{NObj} c_{y1}{}^{Pac} a_{x2}{}^{VTt} a_{y2}{}^{NObj} c_{y2}{}^{Pac},\end{aligned} \quad (14)$$

where: $a_x{}^{NSub} c_x{}^{Ag}$ is a normalized form of the subject variable $a_x{}^N$. Since the subject variable c_x does not influence semantic equivalence between collocates in such predicates as γ_1 and γ_2, we can neglect it for nouns a_x, which are main words in collocates.

As a result, the predicates of collocations that satisfy these characteristics will be equal unity. Otherwise, the predicate equals zero when two collocations are semantically dissimilar. For example, semantically dissimilar collocations:

a tale $a_{x1}{}^{NSub}$ $c_{x1}{}^{Ag}$ ***is checked*** $a_{y1}{}^{Apr}$,
verify $a_{x2}{}^{VTr}$ ***a story*** $a_{y2}{}^{NObj}$ $c_{y2}{}^{Pac}$,

where: words ***a tale*** and ***a story*** are similar, ***to check*** and ***to verify*** are similar too, though the collocations ***a tale is checked*** and ***to verify a story*** are dissimilar because it does not satisfy equation 14. Although according to 10 and 14 collocations ***a tale is checked*** and ***a verified story*** are similar:

a tale $a_{x1}{}^{NSub}$ $c_{x1}{}^{Ag}$ ***is checked*** $a_{y1}{}^{Apr}$ ≈
≈ ***a verified*** $a_{y2}{}^{AAtt}$ ***story*** $a_{x2}{}^{NSub}$ $c_{x2}{}^{Ag}$.

Let's take a look at another example:

a decision $a_{x1}{}^{NSub}$ $c_{x1}{}^{Ag}$ ***influences*** $a_{y1}{}^{VTt}$ and
affect $a_{x2}{}^{VTt}$ ***a resolution*** $a_{y2}{}^{NObj}$ $c_{y2}{}^{Pac}$,

where: words ***a decision*** and ***a resolution*** are similar, ***to influence*** and ***to affect*** are similar too, though the collocations ***a decision influences*** and ***to affect a resolution*** are dissimilar because it does not satisfy the equation 14.

Although according to 12 and 14 collocations ***a decision influences*** and ***a resolution affects*** are similar:

a decision $a_{x1}{}^{NSub}$ $c_{x1}{}^{Ag}$ ***influences*** $a_{y1}{}^{VTt}$ ≈
≈ ***a resolution*** $a_{x2}{}^{NSub}$ $c_{x2}{}^{Ag}$ ***affects*** $a_{y2}{}^{VTt}$,

and according to 13 and 14 collocations ***influence a decision*** and ***affect a resolution*** are similar too:

influence $a_{x1}{}^{VTt}$ ***a decision*** $a_{y1}{}^{NObj}$ $c_{y1}{}^{Pac}$ ≈
≈ ***affect*** $a_{x2}{}^{VTt}$ ***a resolution*** $a_{y2}{}^{NObj}$ $c_{y2}{}^{Pac}$.

CONCLUSIONS

The main result of the study is the logical-linguistic model of collocation similarity for Ukrainian and English languages. The model allows extracting semantically equivalent collocations from semi-structured and non-structured texts in Ukrainian or in English. Implementation of the model will allow to automatically recognize semantically equivalent collocations. Usage of the model allows increasing the effectiveness of natural language processing tasks such as information extraction, ontology generation, sentiment analysis and some others.

In the future research we intend to broaden the scope of the study on semantic equivalence. This study has shown that the grammatical dependency of main and dependent words should be taken into account together

with their grammatical and semantic characteristics. The main challenge is to discover semantic similarity between NN and $N^{of}N$ collocations.

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Mathematical modeling and research results of the strainedly state of polymer tape in the sealing tape rolls

Andriy Zdobytskyy

Lviv National Agrarian University; e-mail: zdanyar31@ukr.net

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Abstract. A new solution of scientific and applied problems of forage provision efficiency was worked out, it is based on the process of optimization of hay bale polymer wrapping tape, physical and mechanical properties of the polymer tape, in particular rheological one having a significant impact on process efficiency and constructive - technological parameters of the wrapping machine. An analytical modeling of technological process of a bale sealing by a polymer tape was carried out, a patterns set of parameters and equation of polymer tapes state depending on the environmental peculiarities was defined. It was described the mode of strainedly state of the polymer tape in order to determine the speed of unwinding and change of the tape length of allowable deformation, uniaxial strain modulus, the wrapper carrier radius and angular velocity. The conditions of stability of a roll was solved numerically by taking into consideration the deformation of the polymer tape depending on uneven Ωpulling force. A graphical dependance on the speed of unwinding of polymer tape υs from deformation and angle φ is shown and it is determined that it should be in the range of 0.5 to 0.7 m / s. I also tested an adequate set of theoretical positions developed using techniques and equipment with software complex of virtual instrumentation created by LABVIEW. This allowed generating and measuring the actual output signals and recording the results. I experimentally investigated the patterns of creeping kernel parameters change co and γ the resolvents for integral equations of polymeric tapes state $R(t,\Theta) = \gamma c_0 e^{-k(t-\Theta)}$ and found their dependance on the ambient temperature.

Key words: deformation, strain, polymer tape, speed of unwinding, mobile platform.

INTRODUCTION

Forage provision is an important and time-consuming process, the most important and responsible operation of which is pressurizing the forage the efficiency and quality of its implementation depends on the productivity of the livestock industry.

Development of tools for wrapping the rolls of hay by polymer tape sealing them both in the field and in barns, and adaptation the parameters of the existing machines balers will improve the quality of the forage and reduce the energy costs.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

There is not enough information in the specialized literature to display the design and harmonization of working bodies of wrapping machines, it constrains the technology implementation of harvesting hay bales and rolls, wrapped in polymeric tape. In most cases the information relates to quality of the forage and the choice of its advanced technology of harvesting and the relevant equipment needed to implement these technologies [5, 6, 8].

Researches on the deformation rheological properties of plants during their compression was conducted by such scientists as (I.A. Dolgov, V.I. Osobov, G.K. Vasiliev, G.A. Averyanova), offering simple rheological models (mechanical models of elastic bodies) , they determined that plant material is not completely elastic, but possesses certain properties of elastic material and is characterized by their elastic modulus and Poisson's ratio. As for hay-sraw materials, which linear deformation is independent of the pressure, these rates are variable. Scientists have found that the value of the modulus of elasticity and coefficient of transverse deformation depends on the density of a plant material during their compression [7, 12].

Analyzing the theoretical statements of roll tape wrapping process I set a number of questions that are needed to be studied. In particular, out of sight remained analytical dependence of compression on the stems randomly embedded in the compressed roll, most of which are flattened and impossible to quantify; deformations that occur under different conditions depending on various properties of hay-sraw mass and polymer tape.

Taking into consideration all these materials will help to justify structural and kinematic parameters of hay bale wrapper and increase the quality of the conservation process (sealing).

OBJECTIVE

Development of theoretical principles of the wrapping rolls process of hay by polymer tape with regard to its rheological properties and based on this study the technical and technological parameters of the wrapper and quality of the execution process of sealing (canning).

MAIN RESULTS

In the process of hay mass rolls wrapping by polymer tape variable load influences on its acting, resulting in its deformation, so it is necessary to determine the analytical equation of state and relationship between the physical and mechanical and kinematic parameters of the wrapping process.

For this we consider a cylindrical roll that rotates around its axis, wrapped in tape that moves around in a circle in a horizontal plane. In the process the radius of the circumference of the roll is changing and the tape tightens it with a different effort.

Suppose that the mobile platform is a point M (Fig. 1), which moves in a circle of radius R, and the roll - point A. In the process, the point M moves at an angle φ.

Let us define the value and point of coordinates M [10, 13, 14]:

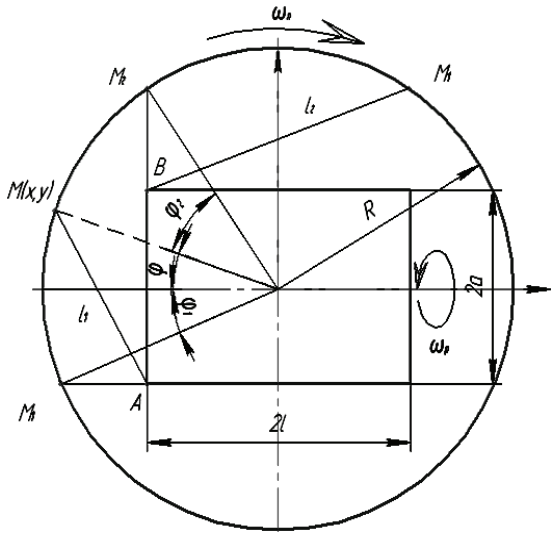


Fig. 1. Scheme of calculation of roll wrapping process.

$$M\begin{cases} x = R\cos\varphi \\ y = R\sin\varphi \end{cases}. \tag{1}$$

According to this the coordinates of point A are:

$$A\begin{cases} x_a = -l \\ y_a = -a \end{cases}. \tag{2}$$

Combining point M and A, we get a segment L1 (the length of the tape), the length of which we find using dependencies (1), (2):

$$L_1 = \sqrt{\left(R\cos\varphi - l\right)^2 + \left(R\sin\varphi + a\right)^2}\ , \tag{3}$$

after simplification we get:

$$L_1 = \sqrt{R^2 + l^2 + a^2 - 2R(l\cos\varphi - a\sin\varphi)}\ . \tag{4}$$

If $\varphi_1 \le \varphi \le \varphi_2$,

where: φ1 and φ2 – the extreme values of angle φ.

Find the extreme values of angle φ:

$$\begin{aligned} \varphi_1 &= -\arcsin\left(\frac{a}{R}\right); \\ \varphi_2 &= \arccos\left(\frac{l}{R}\right), \end{aligned} \tag{5}$$

where: *l* - half the total length of the roll.

In the process, the point M moves at an angle φ (current position M2). According to this the arm length changes due to unwinding and deformation of the tape. The tape will touch the roll in point B. Find the length of the segment M2B that is even to L2, where:

$$L_2 = \sqrt{\left(R\cos\varphi - l\right)^2 + \left(R\sin\varphi - a\right)^2}. \tag{6}$$

Simplifying the expression (6), we get:

$$L_2 = \sqrt{R^2 + l^2 + a^2 - 2R(l\cos\varphi + a\sin\varphi)}\ . \tag{7}$$

To ensure efficiency of the process the condition is required $\varphi_2 \le \varphi \le \varphi_3$,

where: φ_3 – the maximum value of angle φ, when the segment M2B moves in the generatric of the cylinder.

Due to this the angle φ_3 is:

$$\varphi_3 = \pi + \varphi_1\ . \tag{8}$$

Find the segments L1 and L2 increase lengths equal to the increase in the length of the tape unwinding and lengthening due to deformation and express their relationship:

$$dL = \frac{dL}{d\varphi}d\varphi\ , \tag{9}$$

respectively:

$$\frac{dL}{d\varphi}d\varphi = \upsilon_c dt + \upsilon_c dt\left[\varepsilon\right],$$

where: υ_c – speed of unwinding tape, m / s; $[\varepsilon]$ – allowable value of tape deformation.

Hence, we find that:

$$\upsilon_c = \frac{dL}{d\varphi}\cdot\frac{d\varphi}{dt}\cdot\frac{1}{1+\left[\varepsilon\right]}\ , \tag{10}$$

where: $\frac{d\varphi}{dt} = \omega$ – the angular velocity of the moving platform, rad / s.

Find the derivatives of expressions (4), (6):

$$\begin{aligned} \frac{\mathrm{d}L_1}{\mathrm{d}\varphi} &= \frac{R\left(l\sin\varphi + a\cos\varphi\right)}{L_1}; \\ \frac{dL_2}{\mathrm{d}\varphi} &= \frac{R\left(l\sin\varphi - a\cos\varphi\right)}{L_2}. \end{aligned} \tag{11}$$

From equation (10) determine the speed of tape unwinding for both cases, respectively υ_{c1} and υ_{c2}, by the formulas:

$$\begin{aligned} \upsilon_{c1} &= \frac{1}{1+\left[\varepsilon\right]}\frac{l\sin\varphi + a\cos\varphi}{L_1}\omega R, \\ \upsilon_{c2} &= \frac{1}{1+\left[\varepsilon\right]}\frac{l\sin\varphi - a\cos\varphi}{L_2}\omega R. \end{aligned} \tag{12}$$

Solving equation (12) by numerical method we obtained graphic dependences of polymer tape speed unwinding υs on its deformation and angle φ (Fig. 2, 3).

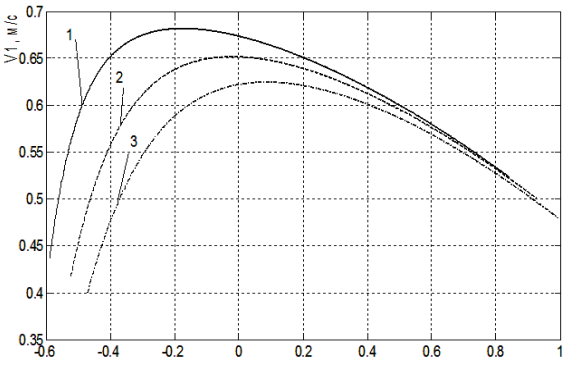


Fig. 2. Dependence of polymer tape unwinding υs1 on the angle φ, relative deformation ε and the condition: φ1 ≤ φ ≤ φ2; 1 – ε = 0,375; 2 – ε = 0,438; 3 – ε = 0,5.

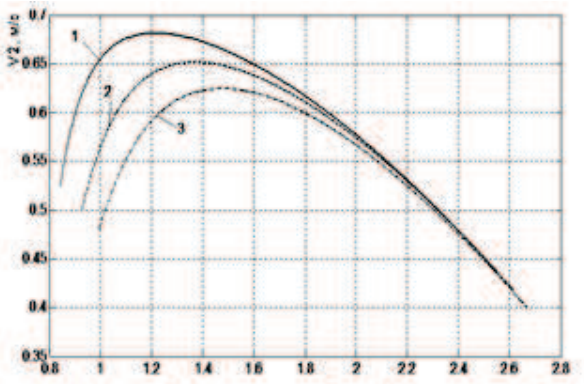


Fig. 3. Dependence of polymer tape unwinding υs2 on angle φ, relative deformation ε and the condition:: φ2 ≤ φ ≤ φ3; 1 - ε = 0,375, 2 - ε = 0,438, 3 - ε = 0,5.

Considering the material of wrapping tape as the elastic-viscous body to which theory of linear elastic creeping is true, we can write integral equation and determine the relationship between deformation $\varepsilon(t)$ and strain $\sigma(t)$ [15, 16]:

$$\varepsilon(\mathrm{t}) = \frac{\sigma(t)}{E(t)} - \int_0^t \frac{\sigma(\Theta)}{E(\Theta)} L(t,\Theta)\mathrm{d}\Theta, \qquad (13)$$

where: $-L(t,\Theta) = E(\Theta)\cdot\dfrac{d\delta(t,\Theta)}{d\Theta}$ is a decreasing function: $\delta(t,\Theta) = \dfrac{1}{E(\Theta)} + c(t,\Theta)$ – complete relative deformation of tape from a single strain; $c(t,\Theta)$ – measure of creeping of the tape's material.

For the known deformation of tape, the equality (13) can be seen as an integral equation with respect to the function: $\dfrac{\sigma(t)}{E(t)}$, the solution of which can be represented as [16-18]:

$$\frac{\sigma(t)}{E(t)} = \varepsilon(t) - \int_{\Theta_1}^t \varepsilon(\Theta)R(t,\Theta)\mathrm{d}\Theta \qquad (14)$$

Further we assume that uniaxial tensile modulus of elasticity (compression) of polymer tape is stabile $E(t) = E(\Theta_1) = E = \text{const}$ as well as the measure of creeping can be represented as follows:

$$c(t,\Theta) = c_0(1 - e^{-\gamma(t-\Theta)}) \qquad (15)$$

where: c_0, γ, – coefficients which should determine experimentally.

Then:

$$L(t,\Theta) = -\gamma c_0 E e^{-\gamma(t-\Theta)} . \qquad (16)$$

Let us find the resolvent $R(t,\Theta)$ of the kernel. For this reason put (16) to (12) and take the time derivative obtained from the equation:

$$\frac{d\varepsilon(t)}{dt} = \frac{1}{E}\frac{d\sigma(t)}{dt} + \gamma c_0\sigma(t) - \gamma^2 c_0 \int_{\Theta_1}^t \sigma(\Theta)e^{-\gamma(t-\Theta)}d\Theta \qquad (17)$$

Excluding from the equalities (14) and (17) the integral, we obtain the differential equation

$$\frac{\mathrm{d}\sigma}{\mathrm{d}t} + \gamma(1 + c_0 E)\sigma = E\frac{d\varepsilon}{dt} + \gamma E\varepsilon \ : \qquad (18)$$

To simplify the equation we will hold a replacement $\sigma = E\varepsilon + z$. Then (18) takes the form

$$\frac{\mathrm{d}z}{\mathrm{d}t} + kz = -\gamma c_0 E\varepsilon(t) , \qquad (19)$$

where: $k = \gamma(1 + c_0 E)$ with the initial conditions:

$$t = \Theta_1; \sigma(\Theta_1) = E\varepsilon(\Theta_1) \Rightarrow z(\Theta_1) = 0 .$$

Find the general solution of homogeneous equation $z_1 = Be^{-kz}$ and the partial of a nonuniform one $z_2 = -\gamma c_0 E\int_{\Theta_1}^t \varepsilon(\Theta)e^{-k(t-\Theta)}\mathrm{d}t$ by constant variation method [19, 20]. Then:

$$z = z_1 + z_2 = Be^{-kz} - \gamma c_0 E\int_{\Theta_1}^t \varepsilon(\Theta)e^{-k(t-\Theta)}dt \ . \qquad (20)$$

From the initial conditions it follows that B = 0, so that we get the following equation:

$$\frac{\sigma(t)}{E} = \varepsilon(t) - \gamma c_0\int_{\Theta_1}^t \varepsilon(\Theta)e^{-k(t-\Theta)}dt , \qquad (21)$$

which implies that the resolvent is:

$$R(t,\Theta) = \gamma c_0 e^{-k(t-\Theta)} . \qquad (22)$$

To find the polymer tape resolvent we should experimentally determine its parameters c_0 and γ assuming that its general deformation remains constant $\varepsilon(t) = \varepsilon_1$ as a result of redistribution of elastic deformation and creeping and there is a strain relaxation with a decline of tape pulling force. [15]

Substituting in (21) $\varepsilon(t) = \varepsilon(\Theta) = \varepsilon_1$ we obtain:

$$\sigma(t) = E\varepsilon_1 - \frac{\gamma c_0 E\varepsilon_1}{k}\left(1 - e^{-k(t-\Theta_1)}\right). \qquad (23)$$

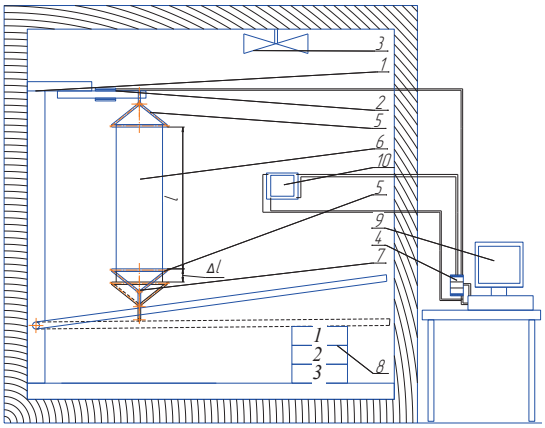
The obtained analytical dependences allow us to justify major structural and kinematic parameters of the process, technological parameters and modes of equipment action that provides sealing rolls. The process of wrapping will be effected by physical and mechanical properties of the tape and due to the nature

of the material it is necessary to investigate it with regard to the time factor.That means to set the equation of state.

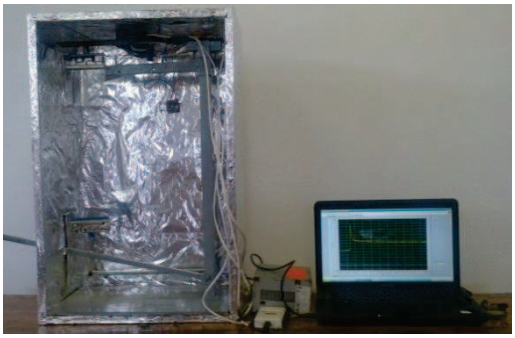
Thus, to determine the main parameters of bale haylage wrapper we should experimentially determine polymeric tape deformation $\varepsilon(t)$ parameters and equation (23) describing its mode of deformation.

Therefore in the process of haylage sealing by a polymer tape roll the deformation occurs in both horizontal and vertical directions by alternating tension and effort of ambient temperature, so it is necessary to determine a link between strain and deformation of the polymer tapes and their dependence on ambient temperature [1 -3].

An experimental device is designed to determine the relaxation properties of polymer tape (Fig. 4).



a)



b)

Fig. 4. A device to determine the relaxation properties of polymer tape: a – the scheme; b – general view.

It consists of a stand 1, to which the plate is fixed with a strain sensor 2 and holders (catches) 5, between which a prototype a polymer tape is fixed 6, to the lower holder 5 it is a lever connected 7, its movement is restricted by the plate 8. For registration and visualization of efforts and the ambient temperature we fixed a temperature-sensitive sensor10 in it, which along with the strain sensor 2 is connected to the motherboard i / o information USB 6008 4, which is connected to the computer 9. The equability of temperature distribution in the heat chamber is regulated by the installed fan 3.

In order to ease and simplify the test equipment we used LABVIEW programming (Laboratory Virtual Instrument Engineering Workbench), developed by National Instruments. This environment is based on the concept of graphical programming of virtual measuring systems and I / O signals and allows you to create applications for the collection, processing and visualization of the defined data.

The software package created in LABVIEW, is a virtual appliance (VA), which refers not only about imitation and the real instruments simulation (Fig. 5). Available in LABVIEW program management of real devices (drivers) make it possible to generate and measure the actual output signals based on their real experimental equipment and record results [4].

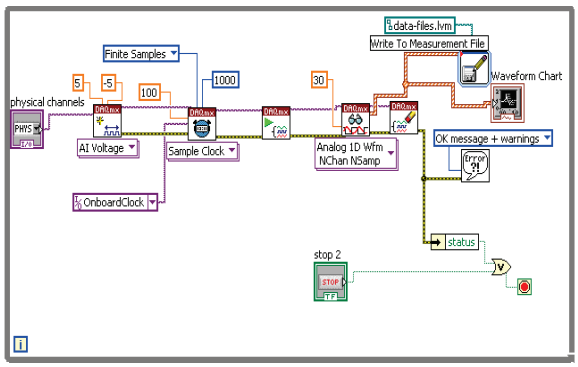


Fig. 5. Block diagram of complex measuring instrumentation.

Investigation of strain relaxation in the polymeric tape was performed as follows. The upper end of sample tape of length of 0.3 m and a width of 0.1 m (see. Fig. 4) was fixed using the strain sensor to the holder, which in its turn is still attached to the stand. The lower end was fixed similarly by the holder to the lever, which drastically loaded the tape sample to the removable plate number 1 and recorded for 2 minutes the elasticity loss of the tape using USB board 6008 and computer software. The second and third samples were studied just as the first one, the difference was the fact that removable plates were loaded to number 2 and number 3, respectively.

This way we recevied the chart of applied force decline over time (Fig. 6) and its dependence on the ambient temperature.

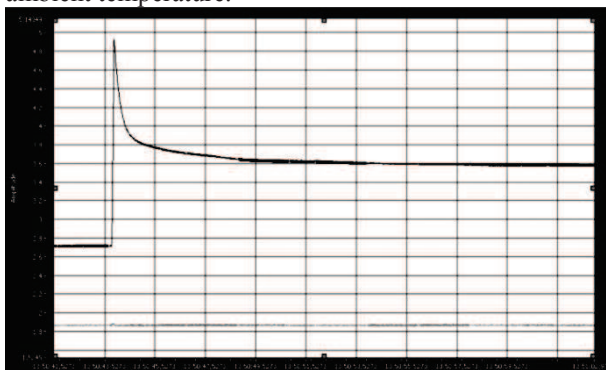


Fig. 6. Sample diagram of pulling force of a polymer tape recession over time and temperature in the chamber (sample tape number 2, temperature 303K, relative deformation 0,375): 1 – curve of relaxation of pulling efforts; 2 - temperature level in the chamber.

From the graph derived by experiment (Fig. 6) we figured out the value of time $t_1 = \Theta_1$, t_2, t_3 and the corresponding values of strength F1, F2, F3 and the value of strain $\sigma = \frac{F}{A_0}$ (A_0 – initial cross sectional area of the tape) [15], wherefrom $E\varepsilon_1 = \sigma_1$, and by making their substitution in (23), received a system of equations for c_0 and γ :

$$\begin{cases} \sigma_2 = \sigma_1 - \frac{\gamma c_0 \sigma_1}{k}\left(1 - e^{-k(t_2 - \Theta_1)}\right) \\ \sigma_3 = \sigma_1 - \frac{\gamma c_0 \sigma_1}{k}\left(1 - e^{-k(t_3 - \Theta_1)}\right) \end{cases}. \quad (24)$$

The system of equations was solved in the following order: firstly we found parameter k from equation:

$$\frac{1 - e^{-k(t_2 - \Theta_1)}}{1 - e^{-k(t_3 - \Theta_1)}} = \frac{F_1 - F_2}{F_1 - F_3} \quad (25)$$

Then calculated the value Δ:

$$\Delta = \frac{F_1 - F_2}{F_1\left(1 - e^{-k(t_2 - \Theta_1)}\right)}, \quad (26)$$

and determined the resolvent parameters c_0 and γ :

$$c_0 = \frac{1}{E}\frac{\Delta}{1 - \Delta}\ ; \quad (27)$$

$$\gamma = k\left(1 - \Delta\right). \quad (28)$$

Having worked out the data we obtained the numeric values of the integral equations resolvent of state c_0 , γ.

CONCLUSIONS

1. We describe the mode of deformation of the polymer tape during the wrapping process (dependences (10), (12)), to determine the speed of unwinding and change the tape length of allowable strain, uniaxial tensile modulus, radius and angular velocity of the carrier.

2. In terms of stability and a roll taking into consideration the deformation of a polymer tape depending on unevenness of pulling force (variable radius) we defined that the speed of unwinding should be in the range of 0.5 to 0.7 m / s.

3. Having conducted the analytical modeling of technological process we found out that in the rheological models the equation of state of the wrapping tape parameters are included as well as the kernel of creeping c_0 and γ parameters, which are necessary to be determined experimentally.

4. Experimental studies have stated that the resolvent of integral equation of state for both types of polymer tapes is as follows: $R(t,\Theta) = \gamma c_0 e^{-k(t-\Theta)}$ whose parameters *C0*, *k*, *Δ* with the increase of ambient temperature are respectively 0.44 - 5.35; 2.7 - 20.46; 0.44 - 0.9, and the parameter γ, conversely, decreases and is 8.55 - 0.84.

5. On the basis of experimental studies we determined the regularities of parameter changes for the equation of state of polymer tapes: for both types of tape tension fall significantly at ambient temperature above 313 K. Its flexibility increases, which makes it impossible to make hayage bale wraps rolling at tape tension efforts over100 N.

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Computerised system of research of automobile and tractor engines

Andriy Holovchuk, Stepan Kovalyshyn, Yuriy Habriyel, Volodymyr Zholobko

Lviv National Agrarian University, e-mail: kovalyshyn@mail.ru

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Abstract. It is offered the automated complex for carrying out experimental researches automobiles and tractors engines with program realization of monitoring of a kind speed-mode on coefficient to non-uniformity of a course. In the developed installation it is automated processes definition, on dynamic modes, the expenditure of air and fuel and coefficient surplus of air and provided an opportunity of a direct estimation of quality of a transitive mode of engines.

Key words: fuel flowmeters, gas meter, shaft speed, the internal combustion engine, electronic diagnostics, personal computer, an electronic controller.

INTRODUCTION

Motor installations for research of internal combustion engines (ICE) nowadays are outfitted with equipment that does not provide the automation of measurement, moreover, it has a low degree of obtained discrete values. Fuel and air consumption and other parameters can be fixed only on the fixed modes. However, during the operating conditions, most of the time, automobile and tractor engines are working on the unsteady modes. Meantime the transient processes of an engine are affecting its technical, economic and environmental performances. Because of the fact the definition of dynamic performance and fuel consumption is an important measure in the study of ICE. In connection with this an urgent problem occurs to develop appropriate methods and tools for automated monitoring and diagnosis of heat engines in different modes.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

While studying transients we frequently use indirect method for determining fuel consumption. One of the examples of this method is the process of oscillography of height change dispensers and moving the rail of fuel pump [1]. On the basis of these values we can determine the fuel consumption. Its instantaneous value can also be determined by filming the fuel consumption from marked pail on the film, followed by rotoscoping [1]. The use of indirect method is accompanied by high material cost and timing, insufficient accuracy values obtained as a result of a number of successive transformations and complex automation of the research processes [2].

Among the most common methods of determining the cost of liquid fuel combustion in ICE we can figure out the mass and volumetric methods [3]. They include the use, as a measurement equipment, mechanical scales and the appropriate level sensors. The main disadvantage of these tools is the complexity of determining small fuel consumption for a short period of time. This is due to low measurement precision and the considerable time delay in stabilization of scales because of the imperfections of the mechanical lever-measuring device and recording equipment. In addition, when we use the volume method for determining the cost of liquid fuel consumption we need to transform volumetric units into mass ones, this requires additional consideration of the environmental factors impact on the value of its density [4].

After analysis of existing methods and tools for measuring fuel consumption, we can figure out a number of unsolved issues: measurement of consumable values with a precision that would have helped to improve the quality of research; decrease the discrete experiment time to a few milliseconds; fast processing of input and output data in graphical or tabular form; providing automated analysis of the character of the ICE high-speed mode of the dynamics and determining the appropriate consumption of liquid fuels.

OBJECTIVES

The aim was to increase the efficiency and accuracy of experimental studies to determine both static and dynamic characteristics of automotive and combine engines using an automated computer system for measuring their individual performance.

THE MAIN RESULTS OF THE RESEARCH

In the basis of an automated computer system is fuel consumption study of different modes of ICE functioning characteristics. This system is designed for automated calculation of the value of fuel consumption by determining its mass quantities in equal intervals.

The basic element of this system is the electronic diesel fuel supply controller [5]. Setting the value of fuel consumption involves measuring its mass in marked pails with help of electronic scales from which we do sampling actions by means of the suppling system of ICE. These measurements are carried out at regular intervals and speed modes.

One of the indicators of the speed modes of ICE is the rate of unevenness of engine operation [6]. The transition from one speed mode to another is monitored

by normalized deviation from the true value of the coefficient of unevenness of engine operation. The novelty of the design is to set the start and the end of the respective engine speed fashion while determining its expense characteristics.

For steady-mode, based on the design and technical features of ICE, the ratio of unevenness is characterized by low change and does not exceed the normalized (critical) value. Exceeding of the critical values of irregularity indicates the end of steady and start of the unsteady mode. If the comparison of real coefficient of unevenness of engine operation towards its normalized value is less than or equals to one, then the speed limit can be considered to be steady, and otherwise – unsteady. After determining the beginning and the end of the speed mode and fixing the instant weight of fuel in the pails we can determine the flow and amount of fuel of the identified speed mode.

The calculation of fuel consumption changes over the duration of the flow of the automatically identified speed mode is implemented by logical and mathematical tools of computer system for discrete numerical values defining the weight of the consumed fuel. The value of the mass of fuel in the marked pails, the crankshaft angular velocity and flow duration of specified speed mode of an engine are the input data to determine dynamic cost of liquid fuels.

A worked out computer system and its main components are presented in Fig. 1.

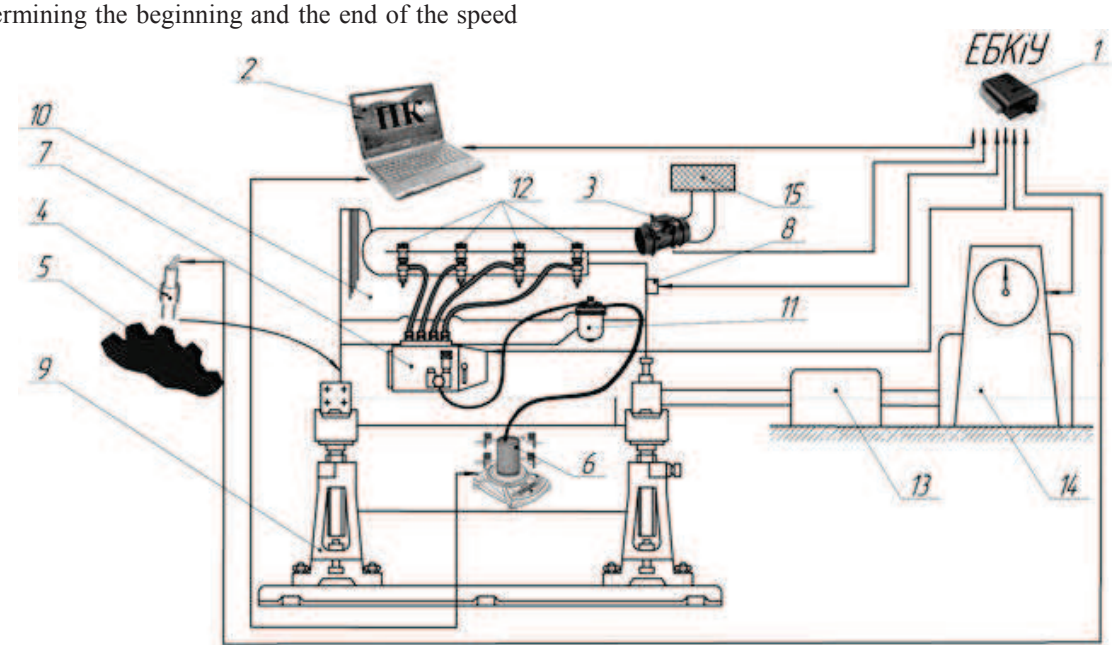

Fig.1. The hardware of a computer system to determine the characteristics of ICE: 1 – electronic control unit; 2 – personal computer; 3 – flow air sensor SIEMENS / VDO 5WK9007Z; 4 – engine speed sensor 21110-3706040; 5 – ICE flywheel toothed crown; 6 – electronic scales CAS MWP-3000H; 7 – high pressure fuel pump UTN-5; 8 – coolant sensor; 9 – bed; 10 – engine under research D-240; 11 – the fuel filter; 12 – jets; 13 – reducer; 14 – measuring stand.

Fig. 2. Diagnostic program window.

To ensure the registration and processing of information signals we use the following test equipment: electronic scales 6, which provide the required accuracy to obtain quantitative characteristics of spent fuel; engine speed sensor 4, for determining the angular velocity of the crankshaft of internal combustion engines; air flow sensor 3, to calculate the value of air flow; and coolant temperature sensor 8.

By means of time differentiation angular displacement of the flywheel toothed crown 5, we make it possible to determine the frequency of rotation of the crankshaft of the engine.

The value of calculating the cost of fuel is carried out by determining its weight in marked pails, which is recorded by the computer system upon the request to electronic scales. In this way, through program-fixed intervals we figure out the fuel consumption from the marked pails.

Diagnostic program developed for the electronic regulator makes it possible to control the current settings of the electronic regulator, and carry out recording of all the measurements to a text file for further processing of the results. A diagnostic program window is shown in Fig. 2. It is divided into several window sills. In the first one "Data", we show the major change of the current settings of the electronic system of fuel supply over the time. In the second - "Characteristics", automatically formed relationship between the position of the rail of fuel supply and the engine speed frequency for the current regulatory fashion is shown. In the lower right corner it shows the current digitized values of input parameters of the system.

In order to test the designed computer system we carried out complex investigations of diesel engine D-240. Experimental studies determined the dynamics of air flow and fuel change, and air excess coefficient depending on the type of high-speed mode fashion. The study was conducted in two stages. The first one was to determine the consumables' characteristics of idling diesel mode. Research results are shown in Figure 3.

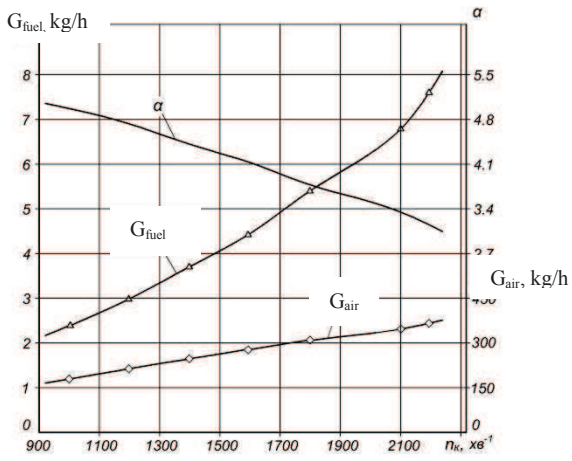

Fig. 3. Consumable characteristics of idling mode, diesel D-240.

In the second stage, we conducted the experiments to determine the dynamics of diesel engine air and fuel intake and excess air coefficient changes in the free acceleration mode. The result of acceleration of diesel at idle from 1000 to 2250 min^{-1} are shown in Figure 4.

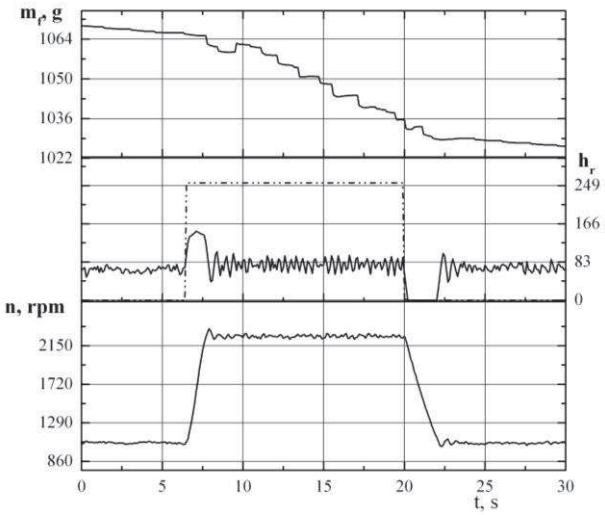

Fig. 4. Dynamics of fuel consumption, the fuel supply track position and frequency of engine rotation for free acceleration mode, diesel D-240

Analyzing the results we can state that unevenness of rotation frequency for the diesel idling is $\delta = 0{,}033$, and the maximum frequency for idling – $\delta = 0{,}028$, which satisfies the requirements for tractor diesel engines. The value of reregulation during acceleration in this case is 3.8%. However, looking at the fig.4 we can state fairly high sensitivity of the electronic fuel supply regulator, leading to a permanent move of rails. We can eliminate this disadvantage by means of software, reducing the sensitivity of the regulator, or to adjust the position of fuel supply rails due to the laws of (P-, PI- or PID-regulation).

CONCLUSIONS

1. This automated computer system extends the area of definition of operating parameters and characteristics of the tractor, combine and other heat engines. It enables to get the dynamic quantitative assessment of fuel, air, and other indicators taking into consideration the coefficient of unevenness of engine operation.

2. In addition to the characteristics of supplies, computer system provides direct assessment of the quality of the transition process, which is characterized by the coefficient of unevenness of pace, overshooting the rotation frequency and duration of the process. This system allows us to conduct dynamic tests of automobile and tractor engines on a much higher lever in comparison with static research with its high complexity and labor intensity of the control adjustment devices.

3. The proposed research system allows us to carry out better and more professional researches and conduct laboratory and exploitation studies of the heat engines; to improve their technical, economic and environmental performance in all modes.

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Study of an air spring with improved damping of vibrations

Anton Masliiev[1], Yuriy Makarenko[2], Viacheslav Masliiev[1]

[1]National Technical University "Kharkiv Polytechnic institute", e-mail: masliew@ukr.net
[2]NPP "Technosintez", e-mail: yuriy_makarenko@mail.ru

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Abstract. The results of the research to substantiate the possibility and feasibility of raising the pneumatic spring suspension system for realization of efficient damping of vibrations of vehicle bodies, which are equipped with such a suspension, are presented. The influence of parameters of system components of the pneumatic spring suspension and gas-thermal and dynamic phenomena in it on the damping factor of vibrations and the development of the amplitudes of the vibrations in laminar and turbulent mode of the air flow through the orifice that connects the air spring and the additional reservoir was revealed. The dependence of the damping coefficient on the cross-section of the throttle orifice and the capacity of the additional reservoir in both modes of the air flow through the throttle was investigated. It was offered to take into account the "active" capacity of the air spring. It was also grounded the influence of natural frequency and density of the air on the damping ratio, which significantly improved the mathematical model that describes vibrations of bogie parts of vehicles on air springs. An example of calculations of the coefficient of damping of the pneumatic spring suspension for the vehicle was given. It is proved that the pneumatic spring suspension allows you to abandon hydraulic or other vibrations dampers completely by proper choosing of its parameters.

Key words: vehicle, air (pneumatic) spring, parameter, throttle, damping, vibrations.

INTRODUCTION

An air spring suspension provides a reduction of costs for repairing and recovery of vehicles and road structures, on which they are moving, because it provides a "soft suspension". This reduces the inertial forces acting on the traffic structure. This is particularly important because restoration of road structures is too costly and requires the expenditure of much labor. Air springs also provide reliable protection of passengers and crew from vibrations and noise that occur when rolling the wheels. This helps to improve their comfort. Therefore, the use of pneumatic spring suspension is considered as a perspective direction of increasing the technical level of vehicles [1-6].

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Pneumatic spring suspension of vehicles requires further improvement, because there is some doubt regarding the performance of the materials of which the pneumatic spring is made, in particular its flexible shell, and insufficient stability of the devices giving the compressed air to it.

Today, the new air spring, in which a flexible shell is not made of reinforced rubber, but of polyurethane, which increased its efficiency, was manufactured and tested in domestic enterprises.

The original microprocessor controller of the position of the body was successfully tested. It allowed to minimize the expenditures of the compressed air for feeding the air spring and provided the stability of controlling of the floor level of the body and the coupler as to the road structure taking into account the load or environmental conditions [7].

Meanwhile, most of the means parallel to the air spring is usually mounted with hydraulic vibrations dampers to provide the proper vibrations damping. And this substantially increases the cost on them and complicates and at the same time reduces the reliability of the pneumatic spring suspension system [8- 11], etc.

Therefore, there is a need for further theoretical and experimental study and characterization of air springs to improve their ability to vibrations damping.

For the air spring the coefficient of vibrations damping β (kg/c) is usually a constant. It is calculated by the oscillograms of vibrations of a mass on the air spring, for example, at the bench [5].

This gives the opportunity for introducing of numerical values of the coefficient of damping in the mathematical and simulation models for the purpose of approximate prediction of the dynamics of the movement of promising vehicles that must be equipped with air springs.

Analysis of the physical processes of the air, which fills the pneumatic spring suspensions system, and also the analysis of experimental oscillograms of the vibrations show that the damping coefficient is not constant. It varies with the variation of the parameters of the constituent elements of the system and modes of

occurrence of gas-thermal and dynamic events in it taking place during vibrations.

Therefore, the results obtained by the mathematical model in which the coefficient of damping is considered constant, is only a first approximation to the results of field tests.

Some steps to reveal the physical phenomena relevant to the formation of processes of vibrations damping in the system of pneumatic spring suspension were made in the work [8]. The authors put forward the hypothesis that the coefficient of mass damping on the pneumatic spring depends not only on the cross-section of the throttle orifice f_{thr} that was already known, but also on the amount of the air G flowing through it. To obtain the necessary dimensionality of the damping coefficient (kg/s), the authors were forced to introduce a proportionality coefficient, which was calculated on the results of experiments at the bench.

Without proper confirmation, it was believed that the dependence of the coefficient of damping β on the amount of the air G flowing through the orifice was linear. This should be considered as a certain approximation that requires validation. Moreover, the value of the quantity of the air G is not a parameter that can be varied, but a variable one, which depends on many factors associated with parameters of components of the system of pneumatic spring suspension. Therefore, the authors defined it as a certain constant.

In the known works of foreign authors on the issue, it is not enough information on attraction systems of pneumatic spring suspension to the realization of efficient damping of vehicles [12-15].

OBJECTIVES

The aim of the study is to ground the possibility of attracting air springs to the realization of efficient damping of vibrations by optimizing the system parameters of pneumatic spring suspension and gas-thermal and dynamic phenomena in it.

THE MAIN RESULTS OF THE RESEARCH

To achieve this goal it is necessary to obtain physically reasonable dependence for the coefficient of vibrations damping and to investigate its adequacy by modeling.

The department of electrical transport and diesel locomotive building HTU "KHPI" initiated, scientifically validated, researched and implemented a pneumatic spring suspension for different series of the long-haul, shunting and industrial diesel locomotives. All these locomotives did not use any dampers, and the damping of the vibrations was reproduced solely by the pneumatic spring suspension system [5].

The required damping of vibrations was first determined theoretically by the prediction of optimum system parameters of pneumatic spring suspension, which were subsequently clarified in the course of numerous experiments directly with the locomotives. During the tests cross-sections of the throttle, capacity of additional reservoirs and so on varied. Apparently, such experiments are too costly and time-consuming.

We believe that the development of scientifically justified methods of theoretical research and calculations of all the parameters and characteristics of the pneumatic spring suspension system for each specific vehicle will facilitate further implementation of air spring suspensions in vehicles, in order to shorten the process of field testing and refinement of the system towards the optimal natural frequency and damping.

We elaborated the basic mathematical model [5], which describes the vibrations of the vehicle body on the air springs, in part, with regards to the mathematical description of damping processes.

Based on the experience obtained during theoretical and experimental researches of vehicles, it was determined that damping of the vibrations depends on the number of ratios: the effective area of the air spring and the cross-section of the throttle orifice F_{eff}/f_{thr}; capacitance of the additional reservoir and air spring $V_{add.r.}/V_{\text{a.s.}}$ etc.

It is necessary to contain in the expression the component or parameter that will determine the part of the energy of vibrations which is turned into thermal energy by diverting it into the environment. It can be influenced by constructive methods. This parameter is the surface area through which heat removal, i.e. the sum of the surface areas of the air spring and the additional reservoir, and sometimes the pipelines connecting them.

Air density $\boldsymbol{\rho}$; "active" capacity of the air spring V_A and resonance frequency of oscillation $\boldsymbol{\omega}$ will affect oscillation damping.

We shall assume the part of the total capacity of the air spring from which air flows out through the throttle orifice during oscillations, to be active. For example, for the "balloon-type» air spring, the active capacity equals the capacity of the air spring, and if it is of a diaphragm or hosiery type, the active capacity will be significantly less than the capacity of the air spring.

Thus, taking into account the above mentioned the following expression for the coefficient of the mass vibrations damping on the air spring is:

$$\beta = (\omega \cdot V_{\text{A}} \cdot \rho \cdot F\ (V_{\text{a.s.}} + V_{\text{add.r.}})(H_{\text{a.s.}} + H_{\text{add.r.}})) / (f_{\text{add.r.}} \cdot V_{\text{a.s.}} \cdot H_{\text{a.s.}}), \text{ kg / c.} \quad (1)$$

To test the adopted assumptions with the use of the MATLAB Simulink software system, there was created a simulation model of vibrations of the chosen wheeled vehicle body on pneumatic springs. We studied its movements on the rough road structure that actuated vibrations.

Taking into account the symmetry of the vehicle, only one point of suspension with one part of the body mass, is examined. Initial data fulfilled the recommended parameters of the vehicle [5, 16]. Natural body vibrations were disturbed by single impulses supplied to the input of the model.

At the first stage of research it has been tested a hypothesis which predicts that upon reaching the speed of sound at the outlet of the throttle by the air flow, "it is choked" and the air completely stops its flow to an additional reservoir. For this throttle sections were varied.

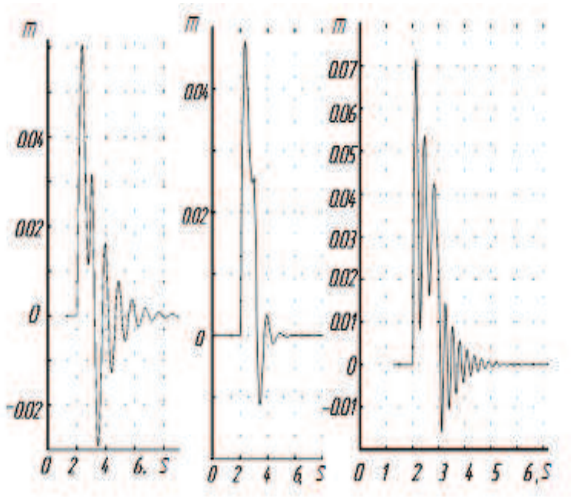
According to the oscillograms, examples of which are given in Fig. 1, the average natural frequencies and logarithmic decrements of vibrations damping were calculated.

Natural frequency of mass vibrations on the air spring is almost unchanged with decreasing of the throttle cross-section from $2 \cdot 10^{-4}$ (a) to 10^{-4} , (b), , and with further reduction of the cross-section it is growing, because the air flow into the additional reservoir is decreasing. Upon reaching the zero value by the throttle cross-section the air flow through the throttle completely stops, the dynamic stiffness of the air spring is increasing, and the frequency of natural vibrations increases about three times (Fig. 2a).

While studying natural vibrations, the phenomenon of rapid increase of their frequency (which can happen, as some researchers consider, when there is "choking" of the throttle, and the speed of the air that flows through it will be "critical", i.e. it will reach the speed of the sound) was not observed.

At the zero value of the throttle cross-section the additional reservoir is completely disconnected from the system. Herewith, the decrement of vibrations decreases almost four times.

Damping of vibrations, according to a logarithmic decrement, was observed mostly at the throttle cross-section in the range of $(0.5–1.1) \cdot 10^{4}\,\mathrm{m}^2$ (Fig. 2, c).



a) b) c)

Fig. 1. Oscillograms of natural vibrations of the part of the body on the air spring with variation of the throttle cross-section.

The dependence of the logarithmic decrement of vibrations on the additional reservoir capacity and its surface is shown in (Fig. 3 and 4), respectively. They are nonlinear, the decrement of vibrations grows faster when increasing the capacity or the surface of the additional reservoir.

In known studies, the mode of the air flow through the trottle is considered as laminar (subcritical), and its flow rate is calculated according to the expression:

$$G = \mu \cdot f_{\text{add.r.}} \sqrt{2\ \rho (P_1 - P_2)}\ , \qquad (2)$$

where: μ is the coefficient of the air flow, P_1, P_2 – the air pressure in the air spring and the additional reservoir, respectively [5].

It is proved in the work [17] that under certain conditions, if:

$$(P_2 / P_1) > 0.528. \qquad (3)$$

The mode of the air flow through the throttle will be laminar (subcritical) and will correspond to the expression (2).

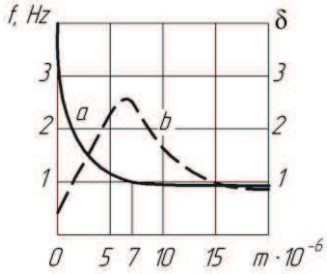


Fig. 2. Dependence of the natural frequency (a) and the decrement of vibrations (b) of the mass on the air spring on the cross-section of the throttle

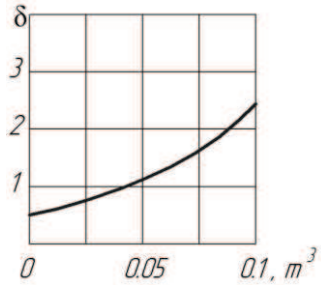


Fig. 3. Dependence of the decrement of vibrations on the capacity size of the additional reservoir when the throttle cross-section is $1.5 \cdot 10^{-4}\,\mathrm{m}^2$

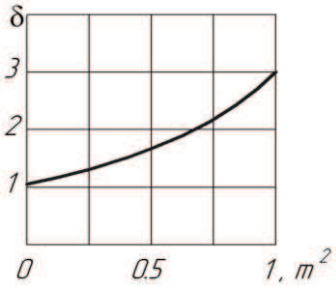


Fig. 4. Dependence of the decrement of vibrations on the magnitude of the surface area of the additional reservoir when the throttle cross-section is $1.5 \cdot 10^{-4}\,\mathrm{m}^2$

If:

$$(P_2 / P_1) \le 0.528, \qquad (4)$$

the mode of the air flow through the throttle will be turbulent (supercritical), and the throttle orifice is not "choked", but retains a certain ability to pass the air. Its mass can be calculated by the formula [17].

$$G = \mu \cdot f_{\text{add.r.}} P_1 \sqrt{\frac{1}{2RT_2}}\ . \qquad (5)$$

The expression (5) is introduced to models together with conditions (3) and (4), which determine the areas of computing, by comparing the pressures in the air spring and the additional reservoir.

These modified models allowed us to study the development processes of forced vibrations of the mass on the air spring for all modes of the air flow through the throttle orifice and to determine the optimal vibrations damping that can be obtained through a system of pneumatic spring suspension.

The mode of the air flow under the terms of (4) is possible when hitting the wheels of the vehicle at a fairly high (or deep) road roughness on the road structure and in the case of resonant vibrations of the body, if the amplitudes of vibrations are large enough.

In Fig. 5 the amplitude-frequency characteristics (AFC) of forced vibrations of the mass of the body on the air spring at sinusoidal excitation with an amplitude of 3 mm for the four (a, b, c, d) modes of the air flow through the throttle: laminar (subcritical), turbulent (supercritical) modes and the mode when the throttle is "choked", or the additional reservoir is disconnected from the system are shown.

They differ significantly from each other in amplitudes of vibrations.

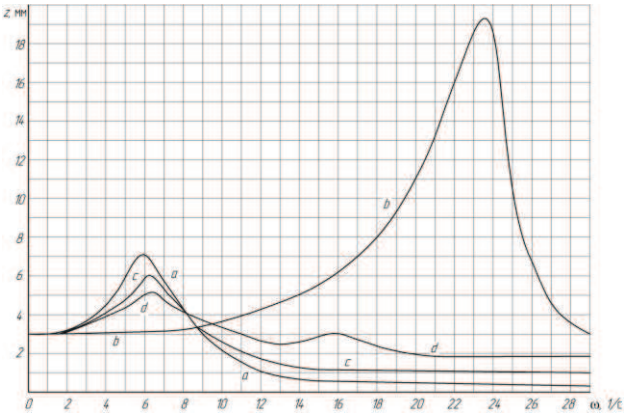


Fig. 5. Dependence of the amplitudes of the vibrations of the mass on the pneumatic spring on a circular frequency excitation when the modes of the air flow through the throttle orifice with the cross-section$\cdot 1.1\cdot 10^{-4}$ m^2: *a* – at the subcritical laminar flow; *b* – at the full throttle choking; *c* – at the turbulent air flow; d – when the cross-section of the throttle is $0.55\cdot 10^{-4}$ m^2.

In the frequency range of disturbances in the range 0 – 4 rad/s when the throttle cross- section is $1.1\cdot 10^{-4}$ m^2, the growth of vibration amplitudes does not exceed 1.5. Afterwards, at the disturbance frequencies in the zone of 4 – 8 rad/s, resonant vibrations are observed, when the amplitudes of the vibrations of the body increase 2.3 times. Further the amplitudes of the vibrations slowly decrease and do not exceed 0.1 mm, even when the frequency of disturbance is 23 rad/s, coinciding with the second resonance associated with a possible "choking" of the throttle, (Fig. 5, *a*).

Therefore, in the frequency range of disturbances 0 – 28 rad/s the phenomenon of "choking" of the throttle was not observed. The absence of resonance at a frequency of 23 rad/s is the evidence of this. Such a frequency is resonant to the air spring without the additional reservoir. That is, when there was such a cross-section of the throttle, the additional reservoir was not disconnected from the air spring.

When reducing the throttle cross-section to $0.55\cdot 10^{-4}$ m^2 and at the same disturbance, the picture changes somewhat: at the frequency of 23 rad/s the maximum appears on the AFC, indicating a partial "choking" of the throttle, i.e. the transition to the turbulent mode of the air flow (Fig. 5, d).

It should be noted that the amplitudes of vibrations in this case are still considerably less than when the additional reservoir is disconnected. That is, due to the flow of the air, the mass of which is calculated by the expression (5), the damping of vibrations decreases, but still remains higher than when the additional reservoir is disconnected (Fig. 5, *b*).

Further reduction of cross-section of the throttle is impractical because the mode of the flow of air through the throttle at the selected perturbance of vibrations becomes turbulent, and the decrement of vibrations damping decreases (Fig. 2, *b*), which can be explained by reducing the mass of the air that flows through the throttle.

As it was expected, the largest amplitudes of vibrations were observed under the mode, when the throttle orifice was "choked" (Fig. 2, *b*), because in this case the flow of the air through the throttle into the additional reservoir disappears, and with it the damping of vibrations substantially reduces because the portion of vibration energy significantly decreases. Then this energy is converted into thermal energy and dissipated into the environment through the walls of the additional reservoir.

Thus, in the system that was studied, two resonances were expected: the first one - at a circular frequency of 6 1/c and the second one – at 23 1/ sec.

But this phenomenon did not find the sufficient evidence during our theoretical studies of the vibrations of the vehicle bodies on the air springs and in the researches of other scientists [6, 18, 19, 20].

The vibrations occur at the AFC, (Fig. 5, *c*) which out of the resonance area is slightly higher than the characteristic, (Fig. 5, *a*) and if the throttle cross-section is selected in such a way that inherent vibrations are damped after three periods, that is, the logarithmic decrement of vibrations is not more than 1.0.

But if the logarithmic decrement of the vibrations is more than 1.4, the vibrations amplitudes decrease in the resonance zone, but out of the resonance area they become somewhat higher, but still a maximum appears, which position along the frequency axis is not clearly determined (Fig. 5, *d*).

This phenomenon we explain by the appearance of disturbance of the turbulent nature of the air flow through the throttle at high frequencies and by reducing the mass of the air that reached the additional reservoir. The system of pneumatic spring suspension in these circumstances is tougher, so its ability to filter the disturbance is somewhat worse.

Thus, when choosing a cross-section of the throttle we must take into account the defined peculiarities of the system of pneumatic spring suspension and carefully choose its parameters, depending on the condition of the road structure and nature of disturbance that can be expected from it.

The damping coefficient of vibrations (2), which is introduced in the simulation model for one of the variants of the pneumatic spring suspension of a vehicle that was investigated, is:

$$\beta = (\omega \cdot V_{\text{A}} \cdot \rho \cdot F\ (V_{\text{a.s}} + V_{\text{add.r.}})(H_{\text{a.s}} + H_{\text{add.r}})) / = / (f_{\text{add.r.}} \cdot V_{\text{a.s.}} \cdot H_{\text{a.s.}})$$

$$= (6{,}0 \cdot 0.012 \cdot 6.6 \cdot 0.129 \cdot (0.012 + 0.04)\ (0.0465 + 0.74)) / (1.1 \cdot 10^{-4}\ 0.012 \cdot 0.0465) = = 40845\ \text{kg/s}.$$

With this numerical value of the damping coefficient the vibrations damp in two or three periods, that is, the logarithmic decrement of the vibrations in this case is about 1.7, which is recommended for vehicles (Fig. 2, *b*).

Consequently, the proposed expression (2) provides the numerical values of the damping coefficient, which is close to optimal, which allows to determine rational parameters of the pneumatic spring suspension system at the stage of modeling and reduce significantly the cost of vehicle test for the purpose of correction of system parameters and to obtain appropriate damping of vibrations.

CONCLUSIONS

1. We improved the mathematical and simulation models in parts, concerning the damping of vibrations by taking into account the influence of system parameters of pneumatic spring suspension and gas-thermal and dynamic phenomena that occur in this system, as well as the mode of the air flow through the throttle orifice located between the air spring and the additional reservoir.

2. We obtained the dependences of vibrations frequencies of the mass on the air spring on the cross-section of the throttle, the capacity of the additional reservoir and the area of its surface, which gave the reason to include them in the expression for calculation of the coefficient of damping, which also takes into account: the density of the air, the active capacity of the air spring and the resonant vibrations frequency.

3. We obtained the amplitude-frequency characteristics of forced vibrations of the mass on the air spring at the variation of the cross-section of the throttle orifice and reducing it to a critical value when the flow of the air through it becomes turbulent and its amount is reduced, which explains the slight increase in out of the resonance part of the AFC.

4. The proposed expression for the coefficient of vibrations damping allows us to define rational parameters of the pneumatic spring suspension system at the stage of designing and reduce significantly the cost of vehicle test for correction of system parameters and to obtain appropriate vibrations damping.

5. The possibility and expediency of involving the pneumatic spring suspension system for realization of optimum damping of vibrations of vehicle bodies were grounded.

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Investigation of contemporary illuminants characteristics the led lamps example

Markiyan Goshko

Lviv National Agrarian University; e-mail: m121314@ukr.net

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Abstract. The problems of investigation of contemporary illuminants characteristics are considered. Particularly the LED lamps of the following trade marks were tested: «Maxus», «Electrum», «Lemaso». Photometric and electrotechnical parameters, stated by the producers, were tested.

The investigation revealed that the stated illuminants' power did not correspond to the actual experimental data, in some cases the 8% exceeding was registered (Lemaso). On the other hand, the actual power of "Maxus" and "Electrum" LED lamps was lower than stated, -22,5 % and -2,35 % accordingly.

The low power coefficient is the major drawback of LED lamps in Ukrainian market. Its actual value ranges are 0,4–0,65, whereas its minimal value for a LED lamp of 5-25 Watt power is considered to be not less than 0,8.

Key words: illuminants**,** illumination, LED lamp, luminous efficacy, power coefficient.

INTRODUCTION

The replacement of incandescent lamps (ICLs) for emitting diode (LED) lamps with light output 5-8 times higher than the LR is considered to be one of the effective ways of reducing electricity consumption for lighting. Despite the obvious benefits, proved in Latvia, the LED lamps are not yet that widespread use of which claim specialists in lighting. One reason for this is the low quality and false information about the products brought to the market Ukraine, causing distrust of consumers. These problems are not unique to Ukraine, but also for industrialized countries. So we decided to experimentally explore available to us modern electric light sources, for example LED - lamps for direct replacement of ICLs.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Advances in semiconductor physics, optics and optoelectronics over the last 10-15 years helped to create light sources to energy efficiency 4-10 times, and duration of combustion in 30-100 times more compared to incandescent lamps. These include solid-state light sources LED (SD). The advantages MD and forecasts for the future development of their lately published in journals lighting unusual amount of materials [1-3].

Many authors believe that today for LEDs not solved one problem - is the high cost of LEDs. Certainly, this is one of the main problems. But she is not alone. The main consumer benefits of LEDs - High luminous efficiency much higher reliability and durability of combustion compared to traditional light sources today - can not always compensate for their shortcomings.

Therefore, the problem of quality, reliability and safety of new light sources, is very important.

OBJECTIVES

Research objectives - to study the real characteristics of LED lamps which come on the market of Ukraine and conformity assessment of the declared data.

THE MAIN RESULTS OF THE RESEARCH

We researched LED lamps trademark «Maxus», «Electrum», «Lemaso» declared in accordance lighting and electrical parameters. For the study was formed three samples (sample) 3-4 LED lamps each. Complex research key features LED - bulbs produce according to method [5].

Manufacturers submitted the following characteristics of light sources:

- LED (Maxus) - 10 W, 900 lm, lifetime of 30,000 h.;
- LED (Lemaso) - 10 W, 900 lm, lifetime of 20,000 h.;
- LED (Electrum) - 10 W, 800 lm, lifetime 2000 h.

Scheme for research performance electric light sources below.

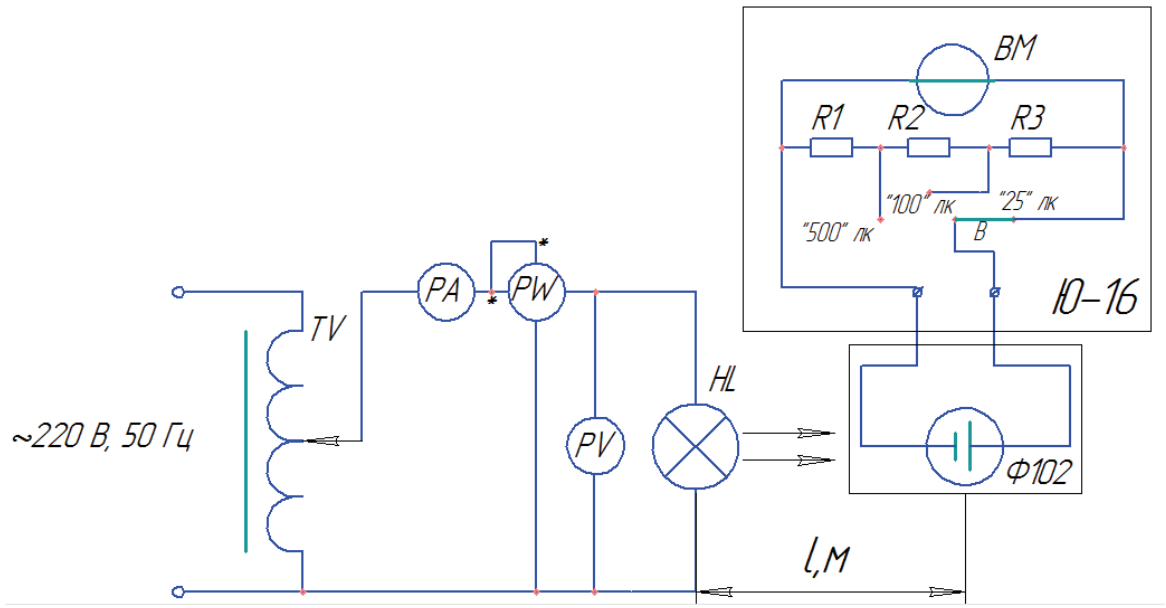

Fig. 1. The study scheme of electrical and lighting parameters of illuminants: TV - autotransformer; HL - investigated the lamp; PA, PV, PW-ammeter, voltmeter and wattmeter respectively; VM - measuring mechanism; B - switch; Ф102 - photocell; Ю -16 - luxmeter.

The value of the measurement results of light and electrical parameters LED - bulbs of various trade marks are given in Table. 2.

After some experimentation, we have indicators for active power at nominal voltage of 220 V, which are listed in the table. 1:

Table 1. Comparative characteristics of passport and measured power values CFL

Type of light source	$P_з$, W	$P_ф$, W	The difference between actual and declared capacity, %
СВД – Maxus	10	8,16	-22,5%
СВД – Lemaso	10	10,9	+8,26 %
СВД – Electrum	10	9,77	-2.35%

The results of the study indicate that among the investigated parties lamps average value of active power on all producers submitted does not meet the declared capacity of the packaging.

Table 2. The results of the LED lamps parameters measurement

lamp type	Parameter	U, B								
		160	170	180	190	200	210	220	230	240
1	2	3	4	5	6	7	8	9	10	11
Maxus, 10 W,900 lm, 30000 hor	I,A	0,06	0,066	0,0705	0,075	0,08	0,0865	0,0925	-	-
	E, lx	475	525	575	615	715	825	925	-	-
	P, W	3,84	4,488	5,076	5,7	6,4	7,266	8,14	-	-
Maxus, 10 W,900 lm, 30000 hor	I,A	0,06	0,065	0,0695	0,078	0,084	0,091	0,094	-	-
	E, lx	495	575	600	670	745	860	945	-	-
	P, W	3,84	4,42	5,004	5,89	6,72	7,644	8,25	-	-
Maxus, 10 W,900 lm, 30000 hor	I,A	0,0595	0,067	0,07	0,076	0,0825	0,0875	0,092	-	-
	E, lx	485	535	610	655	725	790	920	-	-
	P, W	3,808	4,505	5,04	5,795	6,6	7,35	8,096	-	-
The average value E, lx		485	545	595	646,67	728,33	825	930	-	-
The average value P, W		3,829	4,471	5,04	5,795	6,573	7,42	8,162	-	-
The average value H, lx /W		126,654	121,9	118,05	111,59	110,8	111,186	113,943	-	-
Reactive power, Q		8,774	10,244	11,548	13,278	15,061	17,001	18,701		
Full power S		9,57	11,18	12,6	14,4875	16,43	18,55	20,405	-	-
Power factor		0,4								

Continuation of Table 2

1	2	3	4	5	6	7	8	9	10	11
Lemaso 10 Вт,900	I,A	0,0395	0,0475	0,0525	0,058	0,0638	0,069	0,075	0,082	0,087
	E, lx	560	750	1010	1090	1160	1240	1330	1415	1500
	P, W	4,108	5,25	6,14	7,163	8,29	9,42	10,725	12,203	13,65
Lemaso 10 Вт,900 lm	I,A	0,04	0,046	0,0525	0,059	0,065	0,068	0,0775	0,081	0,086
	E, lx	550	760	1000	1090	1150	1225	1350	1410	1450
	P, W	4,16	5,111	6,14	7,32	8,45	9,282	11,083	12,147	13,46
Lemaso 10 W,900 lm	I,A	0,0398	0,046	0,053	0,059	0,065	0,068	0,0763	0,082	0,088
	E, lx	555	750	980	1075	1170	1200	1350	1430	1490
	P, W	4,1392	5,083	6,201	7,287	8,45	9,32	10,904	12,26	13,65
The average value E, lx		555	753,3	996,67	1085	1160	1221,67	1343,3	1418,3	1480
The average value P, W		4,136	5,147	6,162	7,256	8,396	9,34	10,904	12,203	13,585
The average value H, lx /W		134,2	146,35	161,74	149,54	138,164	130,82	123,2	116,23	108,95
Reactive power, Q		4,835	6,018	7,204	8,483	9,816	10,918	12,748	14,267	15,88
Full power S		6,363	7,92	9,48	11,16	12,92	14,37	16,78	18,77	20,9
Power factor		0,65								
Electrum 10 W, 800 lm, 20000 hor.	I,A	0,1075	0,1025	0,098	0,0935	0,089	0,085	0,0805	-	-
	E, lx	1095	1125	1155	1175	1205	1275	1360	-	-
	P, W	9,46	9,584	9,702	9,78	9,79	9,82	9,74	-	-
Electrum 10 W, 800 lm, 20000 hor.	I,A	0,105	0,1025	0,096	0,0925	0,0875	0,0835	0,08	-	-
	E, lx	1025	1095	1175	1205	1225	1275	1345	-	-
	P, W	9,24	9,584	9,653	9,67	9,625	9,64	9,68	-	-
Electrum 10 W, 800 lm, 20000 hor.	I,A	0,105	0,101	0,095	0,092	0,0863	0,0825	0,08	-	-
	E, lx	1075	1100	1150	1200	1215	1250	1375	-	-
	P, W	9,24	9,44	9,405	9,614	9,49	9,53	9,68	-	-
Electrum 10 W, 800 lm, 20000 hor.	I,A	0,11	0,105	0,1	0,094	0,088	0,084	0,0825	-	-
	E, lx	1025	1080	1125	1185	1215	1260	1325	-	-
	P, W	9,68	9,82	9,9	9,823	9,68	9,702	9,98	-	-
The average value E, lx		1055	1100	1151,25	1191,25	1215	1265	1351,25	-	-
The average value P, W		9,405	9,607	9,66	9,7185	9,65	9,67	9,78	-	-
The average value H, lx/W		112,17	114,5	119,12	122,578	125,96	130,77	138,3	-	-
Reactive power, Q		14,281	14,588	14,676	14,757	14,647	14,688	14,837		
Full power S		17,1	17,47	17,57	17,67	17,54	17,59	17,77	-	-
Power factor		0,55								

Based on this study can be stated that when the supply voltage in the range of 160-240 in luminous flux, power, light returns virtually unchanged paws Electrum only 10 W (Fig. 2 - 4), according to Table 1. These lamps power unit functions as a stabilizer power. As for the other two producers - namely brand Maxus and Lemaso, nature changes the luminous flux of light return from the supply voltage has a different relationship. This relationship is represented graphically in Fig. 2.

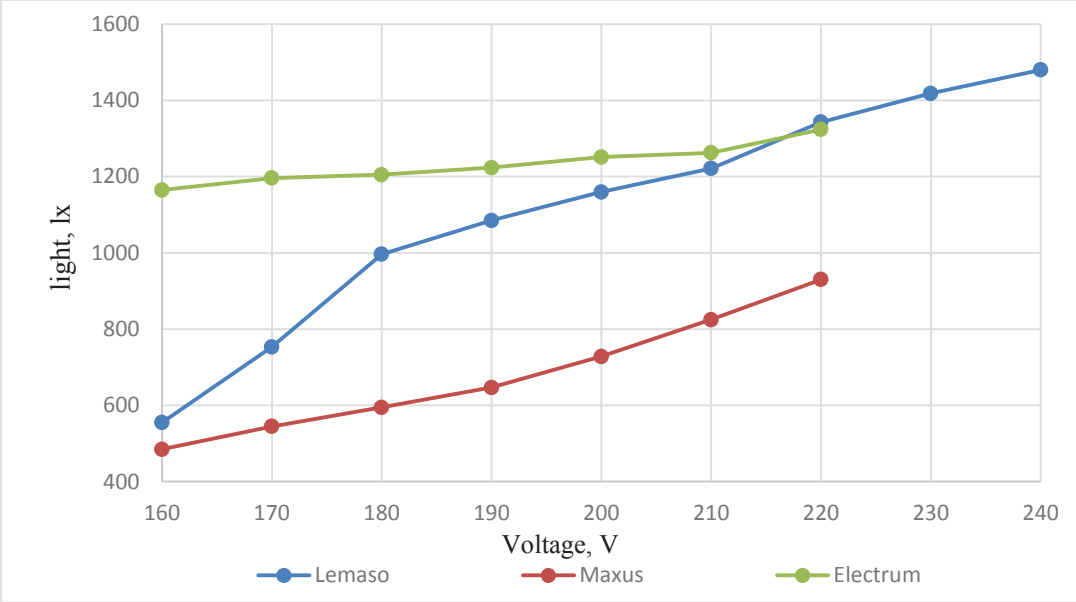

Fig. 2. Dependence of illuminants' illumination on voltage supply.

The criterion is enerhoekonomichnosti luminous efficiency lamps. Cross structures investigated CFLs graphically depicted in Figure 3.

The most effective is the LED lamp company Electrum, whose luminous efficiency at the rated voltage of 220 V has a maximum value - 138.3 lux / W.

A major drawback of LED - lights coming in the market of Ukraine is the low power factor (cos φ). We have studied the power factor LED - lights manufacturers Maxus, Electrum and Lemaso ranges 0,4-0,65, although according to the Cabinet of Ministers of Ukraine on October 15, 2012 №992, the minimum allowable values of power factor LED lighting for indoor lighting devices public and industrial buildings with capacity from 5 to 25 W should be at least 0.8. Low power factor data of lighting requires more reactive power compensation lighting network, to improve technical - economic indicators for power supply and reduce energy losses.

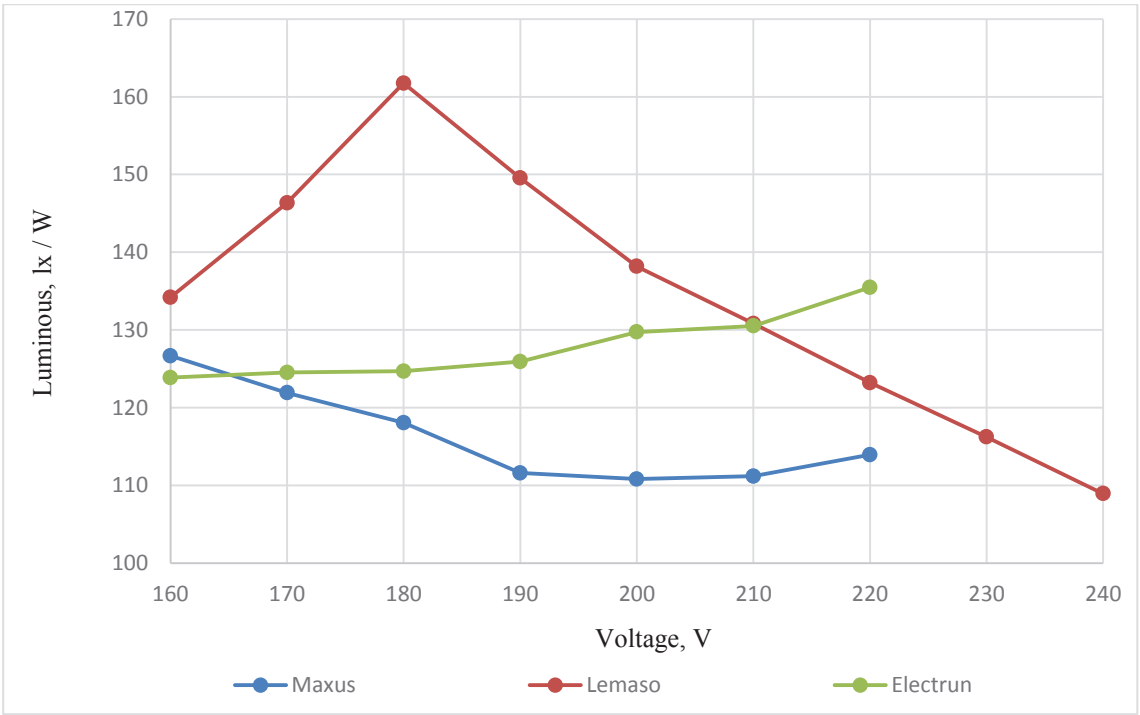

Fig. 3. The dependence of the LED lamps light output on voltage supply.

On the basis of measurements and calculations determined the dependence of active, reactive and full power from the supply voltage Fig. 4.

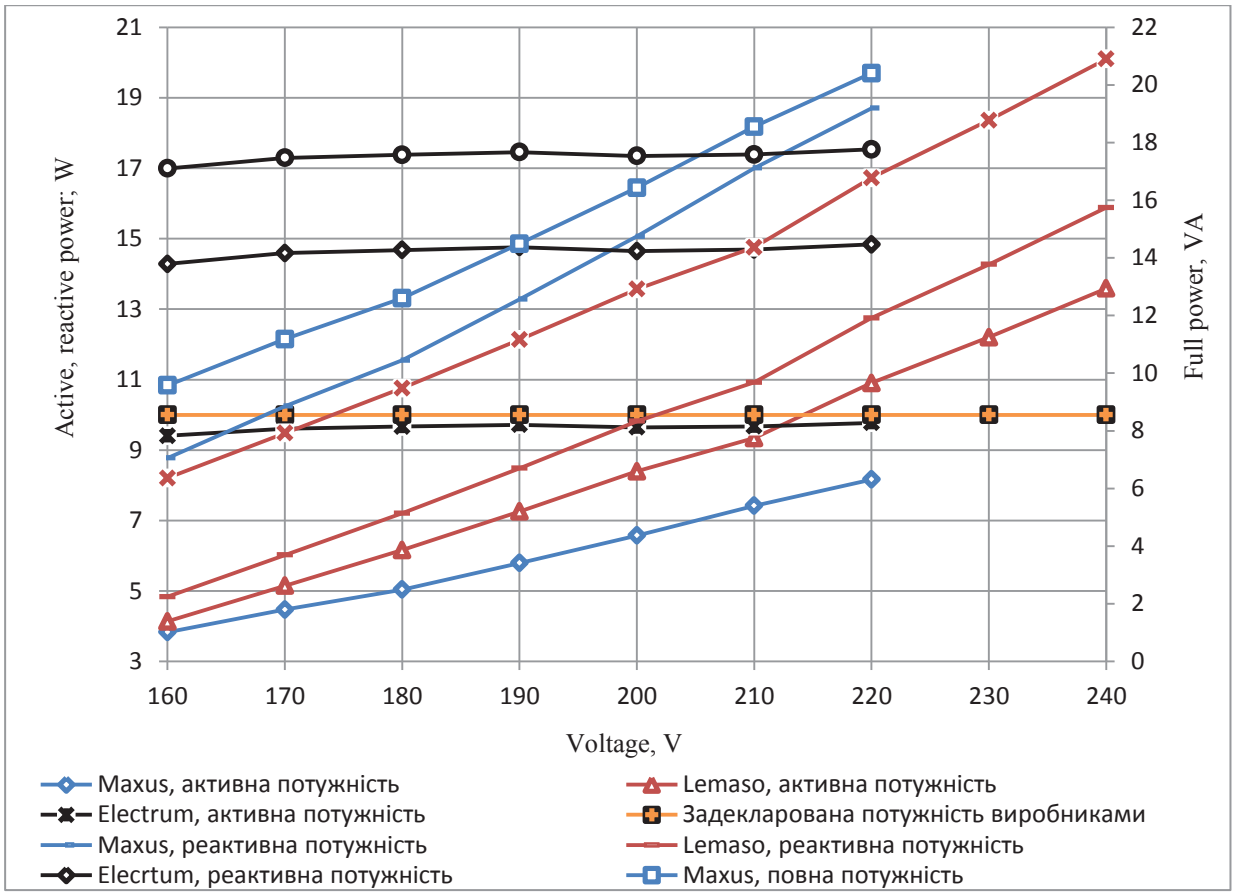

Fig. 4. Dependence of LED lamps power (active, reactive, and apparent) on voltage supply.

CONCLUSIONS

LED - lights are promising light sources for special and for general lighting, but much of lamps which come on the domestic market of Ukraine does not correspond to the declared lighting, electrical parameters as we see from studies investigated the alleged power trademarks LED lamps do not meet experimentally removed the data, in some cases exceed by more than 8% - LED (Lemaso), although it should be noted that at times it was lower than declared - LED (Maxus, Electrum) respectively -22.5% and -2.35% .

In turn for light output at the rated voltage of 220 data LED lamps can rank in this spinning wheel:

1. LED (Electrum) - 135,5 lx / W;
2. LED (Lemaso) - 130,8 lx / W;
3. LED (Maxus) - 113,94 lx / W.

A major drawback of LED lamps coming to market in Ukraine is low power factor, which ranges from 0,4-0,65, while the minimum allowable values of power factor for LED lighting devices with capacity of 5 to 25 W should not be less than 0 8.

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Optimization of information flows of logistic supply chain

Myroslav Oliskevych

National University "L'vivska Politekchnika", e-mail: myroslav@3g.ua

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Abstract. This research is devoted to the problem of information flows of logistic system of goods supplying. Information messages appear at moment of material flows which should be consider as discrete one. It gives an ability to research all changes that can occur to input material flow. Moreover, it makes a possibility to obtain analytic dependence of showers of effectively of system from parameter of information and material flows interaction. Logistic chain was first decomposed on four basic logistic operation such as distributing, unitizing, breaking up, speed up. Three parameters were used to characterize them. All that parameters depend of main flow of goods, packets, transport packets. The principle of solid material flows was applied. Then points of control were defined. It was researched two parts of main problem. First deals with a increasing material flows and consequences of logistic chain adopting after that. Second deals with an decreasing flow. Control of several ways of different changes of logistic schemas depends of existed information flows which may be sent at one of defined control point. The criteria of material and information flows interaction effectiveness is total time delay per unit. The principle of streamlining is just-in-time. Deviation of appointed moment of operation starting or finishing equals to additional costs. The result consists the dependence of total delay per unit from structure of information flows. It can be used as a condition of real logistic schema optimization.

Key words: logistic chain, material flow, information flow, time delay.

INTRODUCTION

According to the development of telemetry and other information-analytical means of transport systems information of logistic events and of traffic and road conditions is becoming increasingly accessible [1]. There were conducted researches and developed implementation to improve the intensity of their use [2]. However the effectiveness of whole available information has not been evaluated at practice yet. Moreover there are short of samples of messages flows optimization. Especially, it relates to large transport and technological systems. No account of the amount of information that is in the real process of goods supplying has been taking before decision making. No estimation of it is not enough or surplus.

It leads to excessive costs of transport process management and process production and delivery of products in general. Also, it was not taken into account that the material and information flow in logistics supply chains of production are interdependent [3]. Therefore a wealth of information nonlinearly depends on the total traffic [4].

It is also clear that the material flows can not be controlled apart from the energy and information flow as ordinal transport processes. For example, many decisions regarding the choice of modes and the interaction within participants of the delivery process are made without even taking the available information, therefore they are subjective often unjustified [5, 6]. This applies, above all, the criterion of delivery organization which is the speed of material flows. It costs a lot resources including energy and often becomes unjustified because violated the principle of "just in time".

That is why this paper is devoted to research problem of supply system control which deals with material and information flows interaction.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Existed material flows of logistic systems are mostly designed after criterion of total costs per unit of cargo transported [7, 8]. They depend on useful loading of trucks, their average speed and technology level. Decisions are made considering the dependence of this parameters on set of routes regarding limitation of maximum speed and trucks loading capacity [7]. They provide expectations of transporters successfully, depending on the market situation. Therefore, they reflect mostly market conditions. To assess the global development of goods delivery system using them is inappropriate. This technique can be used for simple marketing networks and when changing the size of the group of goods in the logistics chain is not expected [9].

Other sources have been seen transport process as a discrete and cyclic [10, 11]. It leads to necessity to divide of general material flow to freight flows and traffic flows. It is clear that it will reach maximum efficiency when these flows will be justified. But this point of problem view does not deals with potential information effectiveness. The task can be solved step by step, using methods of dynamic programming. In some cases, getting optimal solution is not guaranteed [12].

The role of information technologies in the forwarding services has been specified in set of paper [3, 6, 8]. The typical structure of the logistic sites providing the search of requests of freight owners and carriers has been described. The analysis of the software for transportation companies was conducted [13, 14]. The perspective directions of improvement of forwarding services process have been revealed [9]. But it was not improved forwarding service development and scientific substantiation of decision support systems in the organization and management of the transport process, as well as providing the flexibility of the developed systems, depending on the specialization and preferences as the customer software. So the urgent matter is to develop the methods of structure optimization of both material and information flows as interacting objects [15, 16].

There is known methods of structural optimization of cycle processes which is defined as the time between movement of the subject of work for the next technological position [17]. It was established that their parameters depend on organizational efficiency of object of labor equipment and technology. That organizational efficiency parameter called tact is defined as the time between movement of the subject of work for the next technological position. Basic manufacturing operations are arranged relatively tact. Temporal and spatial interdependence is conditioned due to the properties of the material and technical basis – object of labor, equipment and technology. This technique is most effective when the subject of labor has a complex hierarchical structure which makes it possible to divide the manufacturing process on interdependent parts [18].

In the circumstances nonrandom variable traffic demand to meet the challenges of transport and justification parameters of technological schemes using methods of stochastic modeling the transport and accumulation system [19, 20]. However, these methods do not consider transportation process as a discrete material flow and, consequently, does not take into account objective performance trucks losses due to organizational and technological forced downtime, resulting disorder logistic operations.

All amount of logistic operations has not been separated into elementary material transformation and events message generation up to now [21]. The analysis of approaches to formalize the cargo delivery process has been resulted at the paper [12]. There was made definitions of basic and complex handling operations. The flow sheet of packaged cargo delivery by motor transport has been defined as a set of basic and additional handling operations. But there were no difference between objects of process flow: no material unit nor message of it's change.

The impact of variable demand on the efficiency of road transport was investigated before [16]. All the researchers tried to take into account the random nature of the transport process through removable cargo. However, they were not taken into account that some disturbance of the transport system leads to its qualitative changes which is not able to effectively ensure the delivery of goods at lower / higher flows. Not enough attention was paid to the interaction of material and information flows in the logistic system (LS).

In recent works Shramenko N. Y. there was built strategies model of behavior of the terminal cargo delivery systems that allow to evaluate the optimal number of different resources on the basis of random demands on transport services [22]. Author also first developed the theory of creating an integrated information system to decide on the formation of transport technologies that make it possible to take into account the interests of all stakeholders and providing shipping maximize the desired effect. However his works do not take into account that the functioning of the LS, especially those that use road or rail, this is their cyclical adjustment to the conditions of material production and consumption that form discrete material flows. There it is on the basis of changes in the structure of the PTS. Thus the course of logistical operations is a source of information flow in the LS.

OBJECTIVES

Intention was to develop a methodology of ordering material and information flows in the logistics system delivery. It would help to increase the efficiency of goods delivery, on the one hand and reduce uncertainty in decision making and additional costs in order to obtain the necessary information.

THE MAIN RESULTS OF THE RESEARCH

The interaction of material and information flows reflected in the dynamic model of transport technological systems, such as graph, whose vertices are a fait accomplished events, called basic logistics operations, and relationships are parameters of interaction such as tact; size physically separated units of material flow, group transport packages; front of elementary operations as amount of material flow, both located between two adjacent peaks; unit capacity material flow during storage, loading, reloading etc. The sample of this model is shown on figure 1 [23].

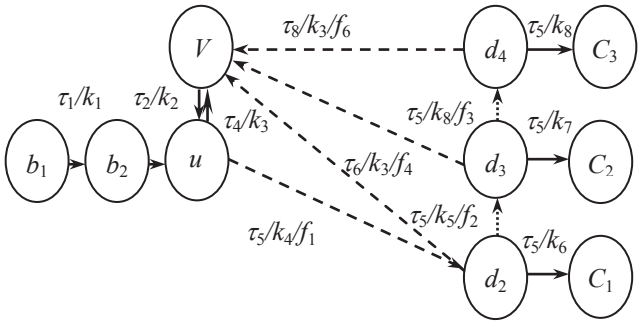

Fig. 1. Example logistic schemes - b_1, b_2 – operations of breaking up flows; u – operation of uniting flows; $d_1 \ldots d_3$ – operation of flows distribution; $C_1 \ldots C_2$ – customers; V – park of vehicles; τ_i – takt; k_i – number of units; f – front of operation.

The great diversity of logistics operations of conversion of material flow at practice can be reduced to four basic logistics operations (BLO) which form complex structures [24]. There are:

- *distributing* BLO - which divide one into multiple discrete material unit, with slower dynamics, with the same size of the group of goods;
- *unitizing* BLO - which have an inverse effect to the distribution;
- *breaking up* BLO - which slow the flows by enlarging the size of the cargo group;
- *speed up* BLO (same - acceleration).

Thus any of LS that can display a graph whose vertices are events - BLO and connectors a change of parameters: tact τ; size physically separated units of the material flow - k; group transport packages; Front BLO - f amount of material units (MU) located between two adjacent vertices; BLO of energy intensity - energy costs pursuant to move the unit of MU - group size along the trunk road, the storage, loading, reloading. The initial parameters of such a model are intensity of goods consumption (bringing them beyond the existing LS) - μ_ξ, where $\xi = 1,\ldots N$ − the number of ending BLO. In general the model can have multiple sources and multiple customers of MU. That is why we are talking about the existence of synchronous chains of same LS. Given the accepted idea of the perfect LS all of them need to be interrelated. Thus, each of the possible BLO can specify dependencies analytical parameters:

$$\text{distributing: } \frac{1}{\tau_i} = \sum_{j=1}^{K} \frac{1}{\tau_j}, \quad (1)$$

$$\text{unitizing: } \frac{1}{\tau_j} = \sum_{i=1}^{K} \frac{1}{\tau_i}, \quad (2)$$

$$\text{breaking up: } \tau_j = \frac{k_j}{k_i}\tau_i, \quad (3)$$

$$\text{accelerating } \tau_i = \frac{k_i}{k_j}\tau_j, \quad (4)$$

where: i, j − numbers, of input and output BLO of LC.

The proposed approach to modeling discrete material flows has at least three advantages over continuous. First, it is able to display any LC as a graphical model. Second, it set deterministic relationships between any BLO researched schemes. Third, it started an opportunity to get solution of transport tasks such as optimization of cargo and traffics, to choice the amount of transport group, to choose packaging that previously dealt within stages. One can get the dependence the input flows parameters of output. For a sample it is possible to set the results of such a problems as:

- to choice the useful loading and effective quantity of trucks to serve the defined LC (Fig. 2);
- to determine the minimum duration of goods delivery after scheme given (fig. 3);
- to determine the minimum costs of LC [24];
- to ground the structure of LC after criteria of minimum flows delays e. t. c. [25, 26].

But on the other hand this model represent stationary logistic processes that take place under the same tact. As matter of fact real goods delivery systems are stochastic. It mostly caused by outputs flows which parameters have a random nature because the same content of customer demand. To obtain necessity characteristic of each BLO behaving under random demand it has been used the same principle of continuity of flow.

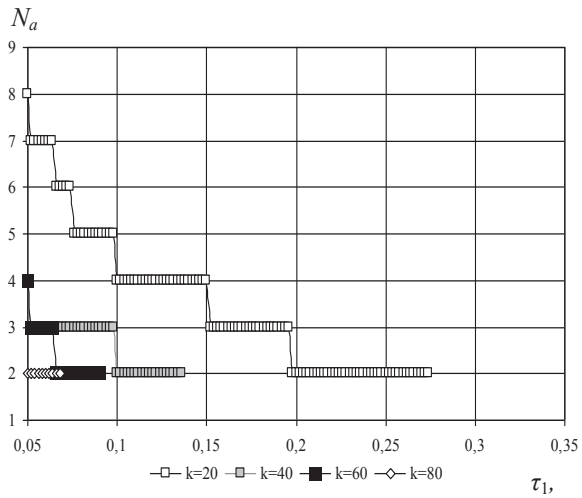

Fig. 2. The dependence of effective quantity of trucks N_a of tact of LS τ under their various loading capacity k.

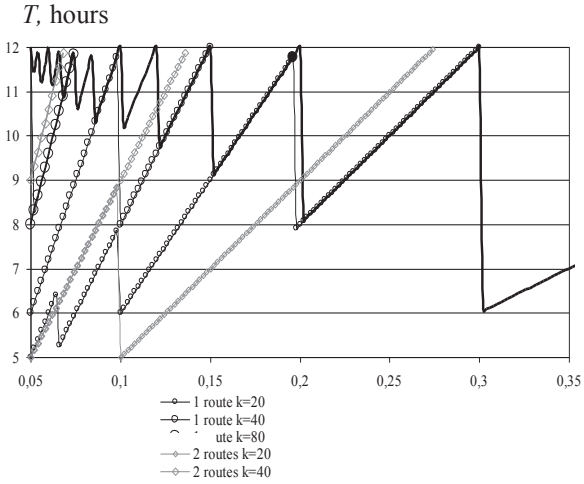

Fig. 3. Dependence of length delivery TD production cycle of τ for various logistical schemes.

Let us consider simple logistic chain (Fig. 4). The operation of manufacturing of goods is providing first under parameter of output flow intensity which is equal to input one μ_m. Packing into consumer package is proving after tact that is determined:

$$\tau_1 = \frac{k_1}{\mu_m}, \quad (1)$$

where: k_1 − size of packaging.

The packing into the overpack has a similar transformation:

$$\tau_2 = \frac{k_2}{k_1}\tau_1, \quad (2)$$

where: k_2 − size of transport packaging.

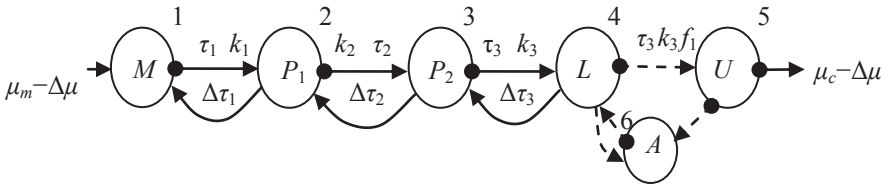

Fig. 3. Model of logistic chain (LC): M – manufacturing, P_1 – packing into consumer package; P_2 – packing into the overpack, L – load on the car, U – unload; A – supply with vehicles; τ_1 ... τ_4 – tact BLO, k_1 ... k_3 – size of group of goods, f_1 – front of vehicles on the route; μ_c – setting the intensity of consumption; $\Delta\mu$ – LC disturbance; 1 ... 6 – IF control points.

BLO of loading is unitizing one so both of goods flow and vehicles flow is synchronized after parameter τ_3. Transportation is the output united flow with the same value of tact. But if it's duration t_{tr} is bigger than τ_3 the front of working vehicles will determine as:

$$f_1 = \left[\frac{t_{tr}}{\tau_3}\right] + 1, \tag{3}$$

where square brackets mean rounded fraction to the upper value. That discretely-event modeling of LC enables to form imagination about the ideal of a logistic system on condition of complete definiteness. If input or output parameter should change under influence of demand of customers it will cause a few changes of LC parameters. Let's consider the transition process of LC. The intensity of output flow may increase / decrease to $\mu_c \pm \Delta\mu$ units per hour any time. But previous BLO are not debugged yet if there is no valuable information. So, point of needing information must be established to prevent material flows interruption. Otherwise the great costs of disordering LC will take place such as unusable assets, unsatisfied demand e. t. c.

If we have decreasing flow $\mu_c - \Delta\mu$ and appropriate information of it is available, the disorder will take place first on control point #1. The dependence of flows should have occurred there is:

$$\mu_c - \Delta\mu = \mu_m - \Delta\mu = \frac{k_1}{\tau_1} - \frac{k_1}{\Delta\tau_1}, \tag{4}$$

where: $\Delta\tau_1$ − the difference between tact of incoming and outcome discrete flows at operation P_1.

Vector $\overline{\Delta\mu}$ directed toward opposite side of basic flow $\overline{\mu}_m$. So the result flow at control point #2 should be:

$$\frac{k_2}{\tau_2} - \frac{k_2}{\Delta\tau_2} = \frac{k_1}{\tau_1} - \frac{k_1}{\Delta\tau_1}, \tag{5}$$

where: k_2 – size of group of goods in the overpack.

Value $\Delta\tau_i$ means a delay of material flow in each BLO_i. To provide all this technologically one need temporary storehouse which costs some value $C_{s,h}$, where h is number of point of control where information is available.

If information of change of output flow intensity μ_c is not available at control point #1 manufacturer will not reduce the output flow with intensity $\mu_m - \Delta\mu$, so next packing BLO P_1 will be executed with constant tact τ_1. It will cause the situation which is similar to previous. But the difference is that the flow delay will equal to:

$$\Delta\tau_2 = \frac{\tau_1 \cdot \tau_2 \cdot k_2}{k_1 \cdot \tau_2 - k_2 \cdot \tau_1}. \tag{6}$$

The value of $\Delta\tau_2$, calculated after expression (6) is smaller than this one calculated after expression (5). The difference we will express as:

$$d_{1,2} = \frac{k_1}{\tau_1} - \frac{1}{\tau_2}. \tag{7}$$

Hence, the $\delta_{1,2}$ is an additional costs C_s^+. It may be compared to a cost of additional information has been given to control point 1 instead of point 2: $C_{inf}^j - C_{inf}^{j+1}$, where: j − number of control point.

Total delay of material flows consists of elements:

$$\Delta_h = \Delta\tau_1 + \Delta\tau_2 + \Delta\tau_3 + \tau_3 \cdot \Delta f_1, \tag{8}$$

where: h − number of operations in critical path of LC.

Structure of expression (8) does not differ if whatever phase of LC will not supply with information of $\Delta\mu$ or not. The difference is about method of elements of (8) calculation. The information presence makes delay of flow bigger if following BLO adapts to changing wave by time reserving, and smaller if it adapts by units reserving.

If we have increasing flow $\mu_c + \Delta\mu$ and appropriate information of it the situation will be the similar. Let us consider it. Suppose that the manufacturer M (Fig. 4) was adopted about the need to increase the material flow in μ value up to time τ_1. Without prejudice to the technology one can do it with the current production capacity by reduction cycle τ_1.

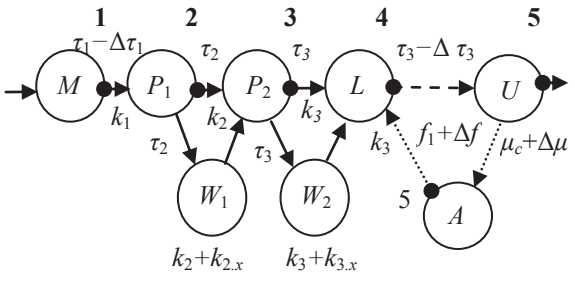

Fig. 4. Detail of the LC model with increasing material flows at $\Delta\mu$.

However, the next phase of LC is BLO packing P_1. Material flow here is not ready to such momentum flux, so the goods remained in storage products exposed. This is shown in Fig. 4 of additional BLO W_1 - storage. As we

see, this input is accompanied by an additional delays of material flow in one clock cycle τ_2. Next phase P_2 is characterized by the impulse and the need for new storage W_2 and new delay τ_3. Reservation is not possible during the operation of transportation of goods, therefore, has to undergo subsequent to accelerate the flow of the value of $\tau_3-\Delta\tau_3$ by using the additional vehicle. The front of them grows to $f_1+\Delta f$. If information of increasing material flows is available at control point 1 the additional costs of LC funding grows to value $C_{w.h}$.

Therefore, in such a LC pulsation of material flows obtained by: (a) reserving production or transport; (b) raise additional funds. Case (a) is characterized by delays in the flow, case (b) means accelerations. Total delays attributable to the positive $\Delta\mu$ only of material flow:

$$\Delta_k = \tau_2 + \tau_3 - \Delta\tau_3 + \tau_3, \qquad (9)$$

Therefore to assess the degree of adaptation to the new conditions LC is advisable to use specific delays in moving their products to the physical unit:

$$\delta_h = \frac{\tau_2}{k_{2x}} + \frac{\tau_3}{k_{3x}} - \frac{\Delta\tau_3}{k_3} + \frac{\tau_3}{k_{3x}}, \qquad (10)$$

where: $k_{2.x}$, $k_{3.x}$ - additional reserved production on phase P_1 and P_2.

Since we are able to calculate the total delay per unit depending of control points available the point of information given would be argument of discreet dependence (Fig. 5).

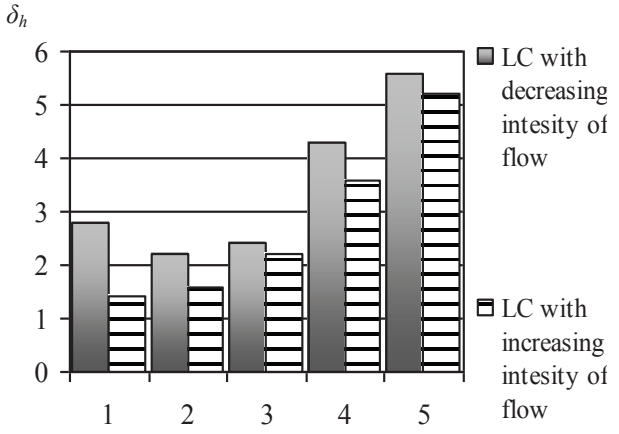

Fig. 4. Dependence of specific material flows delays from available information at existence points of control.

As it shown about the decreasing material flow has more significant influence on supplying chain than increasing no matter of point of information presence. This difference caused by nature of adopting process. As $\Delta\mu$ is negative for at least one cycle period the majority of operations is transforming by creating reserve of objects of material flow for example goods, packets, transport package etc. Otherwise, if $\Delta\mu$ is positive, main type of transforming is capacity reserving for example by acceleration of packing, transporting, warehousing. But this advantage is not absolute. If input flow has changed under intensity $\mu+\Delta\mu$ then next operation must be fulfilled in cycle tact $\tau_1 - \Delta\tau_1$. If duration of operation t_1 can't be reduced and $t_1 > \tau_1 - \Delta\tau_1$ then reserving by capacity of BLO_1 is not possible.

Then next ways of problem solving would be: (a) additional means involvement such as packing machines, vehicles, warehouse etc.; (b) reserving by objects of operation $k_1+\Delta k$, since:

$$\mu_m + \Delta\mu = \frac{k_1 + \Delta k}{\tau_1 - \Delta\tau}, \qquad (11)$$

where: Δk - additional objects of material flow.

The way (a) is the most expensive one. There are no needs of valuable information to provide it. But this is may be the only mode of LC changing in right functioning. It is obviously that way (b) of increasing intensity by Δk has restriction because of k_1 integer too.

We can use such a methods of flows adjustment in case of positive $\Delta\mu$. Taking into account all possible ways to achieve value of increased intensity of material flows in LC, according to formulas (11), we can express character of dependence shown by fig 5. Next expression will help us:

$$\mu_m - \Delta\mu = \frac{k_i - \Delta k}{\tau_i + \Delta\tau}. \qquad (12)$$

Here acceptable ways are: (a) decrease the size of goods packed as solid unit; (b) increase cycle tact. Method (a) leads to necessity of excluding the part of k_i to store it up to the next appropriate situation. As a matter it needs additional warehouses and other means and may be limiting applied because integer value of k_i. Method (b) deals with process capacity which must be decelerated. It is the most popular way to achieve the cheapest flows adjustment. But it needs a proper information flows. That is why the dependence of δ_h from control point (see fig. 5) is increasing in steps. The information is big assets at the beginning of supply chain. By contrast decreasing flows demand a proper information flows in the medium of LC.

CONCLUSIONS

1. Material flows of logistic chain of goods supply my be modeled as discreet system which consist four basic elementary operation which reflex all changing of production delivery.

2. Proposed approach to modeling has few advantages over continuous. It is able to display any LC as a graphical model. It set deterministic relationships between any BLO researched schemes. It started an opportunity to get solution of transport tasks such as optimization of cargo and traffics, to choice the amount of transport group, to choose packaging that previously dealt within stages. The dependences of parameters of LC from cycle tact τ and size of group k prove this advantage since they determine the critical values of tact which respect best effectives of goods delivery.

3. The model of constant input parameter tact is stationary. There are no information messages generated by it. But real logistic system work under influence of various condition. So, changes of material flows are accompanied with information flows which can be used to make the results of its influence more effective.

4. All adopting changes of LC can be adjusted by three elementary methods: (a) additional means involvement; (b) change a cycle tact; (c) change a size of.

5. Increasing material flows are sensitive to information serving. Their dependence of point of message supply is discrete increasing. They should mostly provide system adopting by acceleration of cycle. That is why the most appropriate information flow direction is first control point of chain.

6. Decreasing material flows have an optimal control point after criteria of total delay located at medium BLO. Their results are less effective.

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The results of compliance determining of warranty duration of cylinder block heads personal repairing of YaMZ-236 motors

Roman Kuzminskyy, Igor Stukalets, Andriy Tatomyr

Lviv National Agrarian University, e-mail: igorstukalets@gmail.com

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Abstract. Based on statistical analysis of technical service companies we figured out some patterns of changes in the annual program of repair heads of cylinder blocks repairs of engines YaMZ-236 and the coefficient of variation of the daily batch of orders for repairs.

We chose one technological station, which enables us to perform all the programs of repairs, and the duration of the process does not exceed one day.

Due to the results of simulation modeling, the process of batches and service contracts for the repair of heads of cylinder blocks of engines YaMZ-236 we calculated the values of indicators for the guarantee-repair duration Tg: coefficient of the requirements satisfaction for warranty repair duration ξ_N and average duration of overguarantee downtimes $\overline{\theta}$ in different years of the technological station working (and, respectively, for different values of the reservation capacity ρ_N) and for different values of TG (and, respectively, for different values of the time- reservation ρ_T) in the case of both direct (FIFO) and reverse (LIFO) order of execution.

Based on statistical analysis of the results of mathematical modeling we determined the dependencies expectation $M[\xi_N]$ and $M[\overline{\theta}]$ of ρ_N and ρ_T for different priority of order fulfillment.

Calculations of total costs were done, directly related to the technological costs for repairs and payment of penalties for violation of the order fulfillment of guarantee repair duration TG. Analysis of total dependences of the values of cost reservation capacity ρ_N made it possible to study the rational order of execution of orders for different values of the duration of warranty repair TG.

Key words: cylinder heads of cylinder block engines, incoming flow of orders for repairs, warranty duration of repairs, factors and criteria for compliance.

INTRODUCTION

The annual programs of repair companies are unstable because of changes in the number of cars in the service area, as well as objective changes in technical condition of vehicles during their exploitation.

Incoming flow of orders to repair any units, including the heads of cylinder blocks, has a stochastic character, because it is a transformed stream of refusals, and the amount of daily orders -δ_i – is a random variable.

Thus, when selecting technological lines (TL) and stations (TS) for repair enterprises we need not only to predict the value of annual repair program for the entire planned period of operation of the TL or TS, but also take into account the variability of the amount of daily batch of orders for repairs.

This problem is further complicated by the need to comply repair warranty duration TG. Warranty repairs TG is determined by the contract signed with the customer to perform services. According to the Law of Ukraine "On protection of consumers of agricultural machines" if the executor of the contract of works and technical services does not execute its work, delays the work and services under the contract, he pays the penalty at a rate of three percent of the cost of undone work or services for each day (hour, if the duration is specified by hours), unless otherwise provided by contract. [16]

Determination at the design stage performance of guarantee compliance duration personalized repair of heads of cylinder blocks of engines is essential to justify the choice of TS to ensure the effective operation of technical service companies throughout the planned service life of the TS.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The results of structural-parametric analysis and synthesis of technological processes of heads of cylinder blocks repairing, engines YaMZ-236, enabled a parametric study of a number of industrial structures of technological stations (TS) of repair of various capacities (Table). [17].

Here we present a well-known dependances of mathematical expectation of daily batch of orders $M[\delta_i]$

and coefficient of variation $\nu[\delta_i]$ of annual program of repair W_P of a repair company (Fig. 1):

$$M[\delta_i]=a_0+a_1 \cdot W_P, \quad (1)$$

$$\nu[\delta_i]=b_0+b_1/W_P, \quad (2)$$

where a0, a1 and b0, b1 - regression coefficients value that are obtained for different brands of technology [1-4]. In [5-15] we justified factors and criteria for compliance TG for impersonal and personal methods of repair. It is determined that Tg compliance factors of a personal repair method are: productivity reservation, time reservation and change of execution order: of orders - direct (FIFO) or reverse (LIFO).

Table. Parametric row of production structures of processing lines of heads of cylinder blocks of engines YaMZ-236 and YaMZ-240 repair in united process flow (fragment).

No. TS	Annual performance Q_P, pcs.	Front of repair *f*, pcs.	Number of workers *u*, persons	Technological cancellation (TC)	Amount of main equipment of various types, pcs.													*PZ*, UAH.
					Kr_1	Kr_2	Kr_3	Kr_4	Kr_5	Kr_7	Kr_8	Kr_9	Kr_{10}	Kr_{11}	Kr_{12}	Kr_{13}	Kr_{14}	
1	**391**	**1**	**1**	Direct flow	1	1	1	1	1	1	1	1	1	1	1	1	1	**497,11**
	427	2	2	Direct flow														534,06
2	391	1	1	Direct flow	2	1	1	1	1	1	2	1	1	1	1	1	1	537,81
	503	**1**	**2**	Ramified														**483,88**

As an indicator of the producyivity performance reservation ratio we adopted the annual program of repairs over the years to the annual performance of TD ρ_N = WR / Qa where Qa - annual performance TD, pcs.

To quantify a reservation time $\rho_T=T_g/M[T_{T.P.}]$ is taken, where M [TT.P.] = 1 day and night - the mathematical expectation of duration of the technological repair process, days and nights.

The criteria for warranty duration compliance we take the coefficient of guarantee satisfaction as to the duration $\xi_N=W_N/W_P$, the average overguarantee downtime $\theta=\Sigma\theta_j/W_\theta$, where W*N* - number of orders executed in compliance with the warranty period; $W_\theta=W_P-W_N$ - number of orders for which repair warranty period has been exceeded.

We also considered various ways of enforcing the duration of the warranty repair TG.

In particular, in the works [1-4, 6-15] determined the character of the compliance criteria warranty repair duration for different values of TG and ρ_N and ρ_T and incoming streams of different uniformity, reasonable TG conditions were justified in both impersonal and personal methods of repair of transmission units [5]. However, in these studies the changes in annual programs for the repair operation period of TL or TD are not taken into account.

Thus, determination of the values of the guarantee compliance duration of personal repair of cylinder blocks heads of engines for specific brand models considering changes in annual program for the years of operation the TL or TD has not yet been implemented.

PURPOSE

The purpose is to set criteria of guarantee compliance dependencies duration of personal repair of cylinder blocks heads of engines YaMZ TD-236 to a defined production stucture and the indicators values of the performance reserve, productivity and time reserve and to justify the rational order of execution of orders for repairs.

MAIN RESULTS

Analysis of statistics of enterprises specialized on technical service of Lviv region showed that the annual program of repair of heads of cylinder blocks of engines YaMZ-236 in recent years significantly changed. We determined the regularities of changes in the annual program of repairs (Fig. 1) and the coefficient of variation of the daily batch of orders for repairs (Fig. 2).

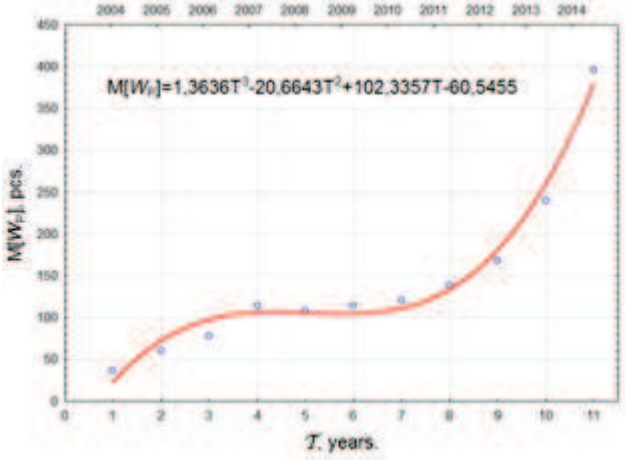

Fig. 1. Model of a year program changes of repair of heads of cylinder blocks of engines YaMZ 236-operation over the years T of exploitation TD.

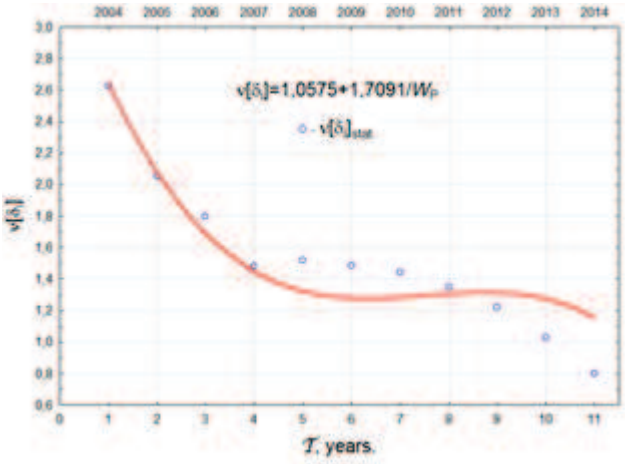

Fig. 2. Model of changes of daily batch coefficient of variation of orders for repair of heads of cylinder blocks of engines YaMZ 236 – operation over the years $\mathcal{T}$, of exploitation TD.

Taking into consideration the maximum value of annual repair programs $W_P^{\max}$ with a pre-synthesized parametric TD of repair of heads of cylinder blocks YaMZ-236 (Table) with the conditions compliance $Q_P^{\max} \geq W_P^{\max}$ we selected TD of the required productivity. This is the first TD with an elementary production structure, where the number of basic repair and manufacturing equipment of all types is Kr = 1 pc. Optimal annual productvity of this TD Q_P^{opt} = 391 pcs., that equals the minimum share of exact technological costs PZtech, and is reached in case of repair of heads of cylinder blocks by one worker (u = 1 pers.), on cocurrent (CC) type of process (f = 1 pc.) and the maximum productivity $Q_P^{\max}$ = 427 pcs. in case of repair of heads of cylinder blocks by two workers (u = 2 pers.) we also have a cocurrent (CC) type of process (f = 2 pcs.).

We conducted a simulation process of batches of orders incoming for service repair of heads of cylinder blocks YaMZ-236. According to the values of mathematical expectation M [δ_i], derived from regression dependence (Fig. 1) we generated Poisson stream of orders for which the coefficient of variation ν[δ_i] corresponds to the theoretical model (2).

It must be noted that during the simulation the value depending on repair programs this year was examined to the corresponding value of the annual performance of the selected TD.

Due to changes in the values of the annual program of repairs over the years τ and exploitation TD, we observe the changing values of the productivity reservation capacity that lie within $\rho_N \in [0{,}09 \ldots 0{,}9975]$ (Fig. 3).

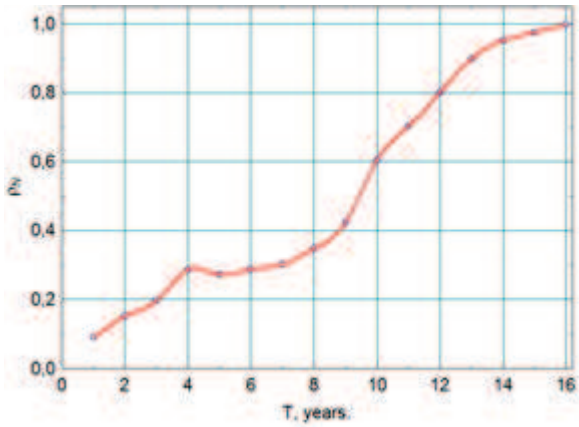

Fig. 3. Change of the values of the performance of the productivity reservation ρ_N by years τ of exploitation TD, according to the accepted models of prediction of the annual program of repair WP = $f(\tau)$.

According to the results of process modeling and service batches of orders for repair of heads of cylinder blocks of engines YaMZ-236 we calculated the values of guarantee repairs duration compliance ξ_N i $\overline{\theta}$ for direct and reverse order of service orders and different values of the time factor of reservation $\rho_T \in [1 \ldots 10]$.

We obtained the dependencies of expectation factor of repairs duration guaranteeing compliance M[ξ_N] on the values of the productivity reservation capacity ρ_N for $\rho_T \in [1 \ldots 10]$ and different priority of order fulfillment (Fig. 4).

We defined that for both direct and reverse order of execution of orders for repairs with the growth of ρ_N the value M[ξ_N] nonlinearly decrease, reaching its minimum in the condition ρ_N=1. Using the time reserve (increase ρ_T) ensures nonlinear increase in the values of M[ξ_N], however, more and more temporal redundancy provides the less growth in M[ξ_N]. The reverse sequence (LIFO) order of fulfillment makes it possible to achieve higher values of M[ξ_N] comparedly with direct one (FIFO).

There were also obtained dependances of mathematical expectancy of everage overguarantee downtimes M[$\overline{\theta}$] on values of productivity reserving capacity ρ_N for $\rho_T \in [1 \ldots 10]$ and different priority order of fulfillment (Fig. 5).

It was defined that with increasing ρ_N values M[$\overline{\theta}$] are nonlinearly increasing for all ρ_T, peaking in condition if ρ_N=1. Low values of everage duration od overguarantee downtimes M[$\overline{\theta}$] can be achieved by increasing the rate time reservation ρ_T, since the increase ρ_T (increase the length of warranty repair TG) provides nonlinear shortening of overguarantee downtime M[$\overline{\theta}$]. Meanwhile, the more time reserve is providing the less reserve shortenings M[$\overline{\theta}$].

Direct sequence (FIFO) of orders fulfillment makes it possible to achieve lower values of M[$\overline{\theta}$] compared to the reverse (LIFO). For example, for ρ_T =2 using the direct order of execution of orders makes it possible to reduce the average length of overguarantee downtime fivefold, compared with a reverse one.

Increase of the value of time reserve ρ_T (increase the length of warranty repair TG) and enables to expand the range of values ρ_N, for which a high level of confidence there will be full compliance with the duration of the guarantee repairs TG (M[ξ_N]=1 and M[θ]= 0 days).

If a certain part orders $W_\theta$was done in violation of the guarantee duration repairing TG (M[ξ_N]<1 i M[θ]> 0 days), then, according to the current legislation, a repair company is obliged to pay compensation to customers of the services Zsh for TG failure.

Thus, the total costs of the repair of heads of cylinder blocks ΣZ include both the actual technology costs Z_{teh},=PZ_{teh}·W_P, which are caused by the production structure of TS, expenditure on wages for workers and work in progress, costs and compensation Zsh for violation of warranty repair duration:

$$\Sigma Z = Z_{teh.} + Z_{sh.}. \quad (3)$$

The results of modeling defined the dependencies of mathematical expectations of the total cost of repairing of cylinder heads M[Σ*Z*] on the values of the time of reservation ρ_T and productivity reservation ρ_N (Fig. 6) for direct (FIFO), and reverse (LIFO) order of orders execution.

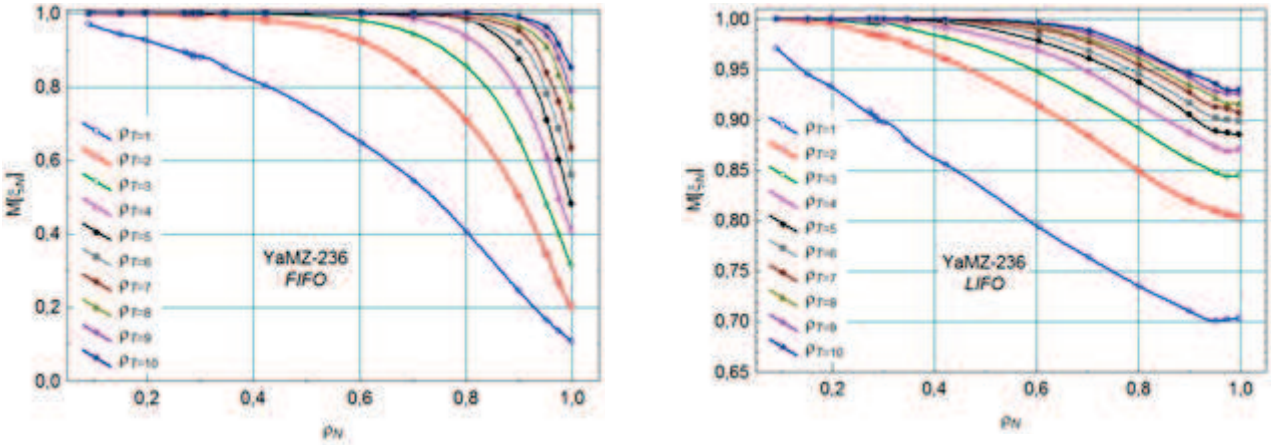

Fig. 4. Dependence of mathematical expectation index of satisfaction of guarantee demands as to the duration of the repair M[ξ_N] on the values of the productivity reservation capacity ρ_N.

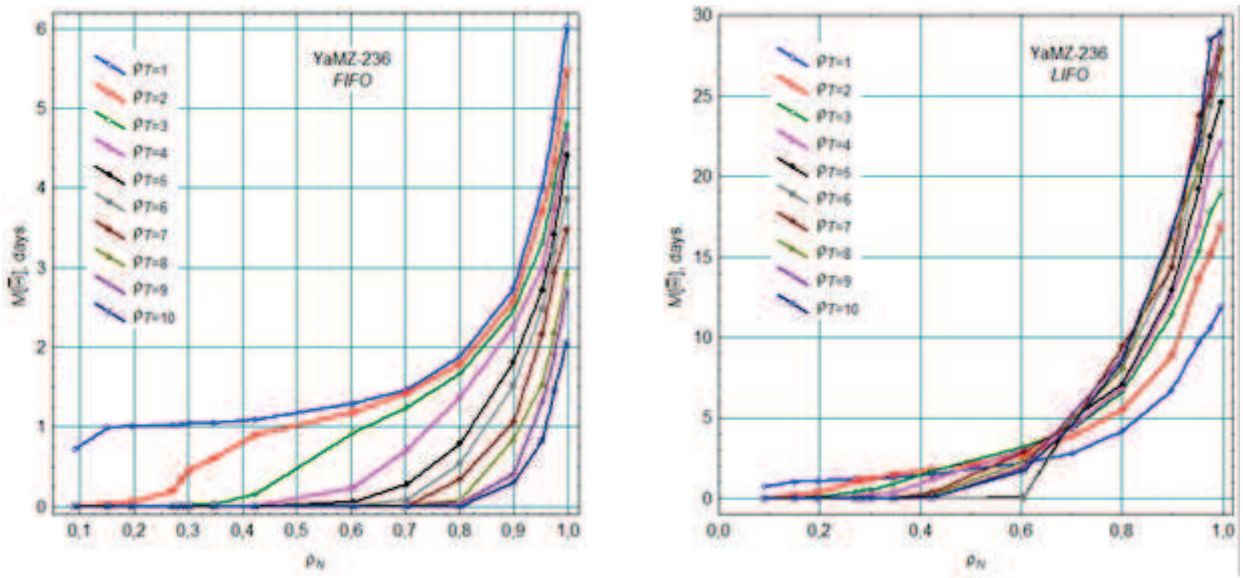

Fig. 5. Dependence of mathematical expectation of everage duration of overguarantee downtimes M[$\overline{\theta}$] of the productivity reservation capacity ρ_N.

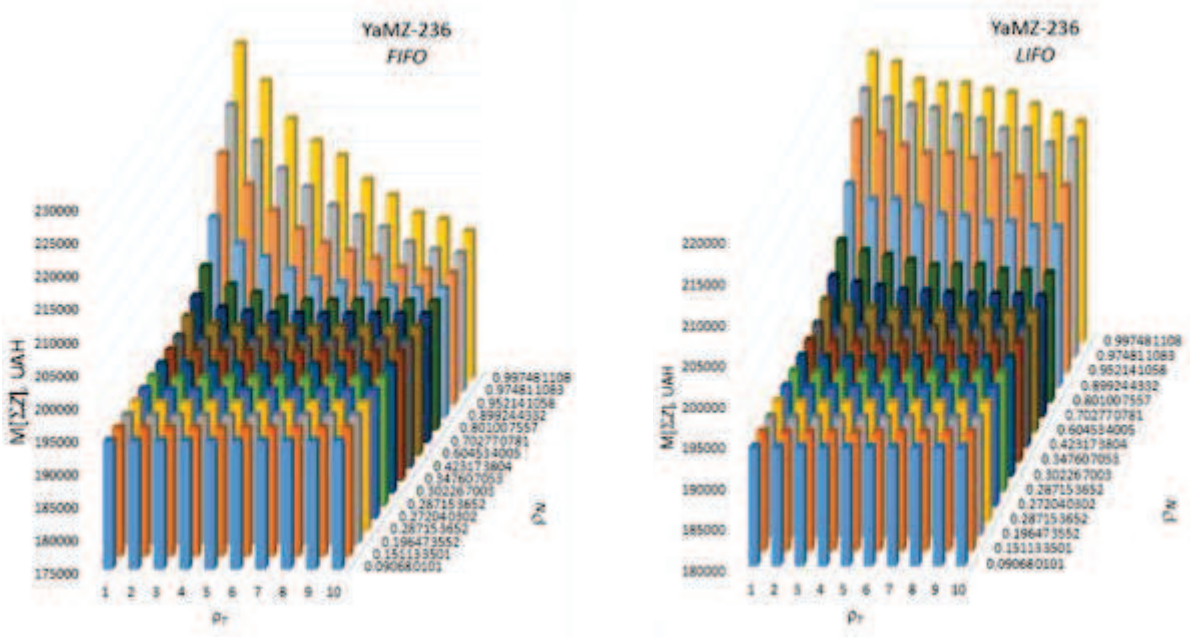

Fig. 6. Dependence of mathematical expectation of the total costs of repairing of cylinder heads M[Σ*Z*] on values of the reservation time ρ_T of productivity reservation capacity ρ_N.

Despite the considerable unevenness of daily orders (coefficient of variation of the daily batch $\nu[\delta_i] \in [2{,}6 \ldots 1{,}35]$) in the range of values $\rho_T \in [1 \ldots 10]$ and $\rho_N \in [0{,}09 \ldots 0{,}6]$, the *Zsh* fines are insignificant, that is why $\Sigma Z \approx Z_{tech}$. With further increase of ρ_N value, the M[Σ*Z*] increases significantly for all ρ_T. In the last year of the TS service, when ρ_N=0,9975, and the coefficient of variation of the daily batch of orders is only $\nu[\delta_i]$=0,8, the mathematical expected total costs M[Σ*Z*] reaches its maximum value by a significant increase in costs failure to compensate customers repair warranty duration violation TG. (eg, ρ_T =1, we have $Z_{sh} \approx 0{,}18 \cdot Z_{tech}$).

Comparison of the M[Σ*Z*] values for different levels of TD loading of a repair service productivity (different values of the performance reserve ρ_N) enabled rational justification service orders priority to repair heads of cylinder blocks (Fig. 7).

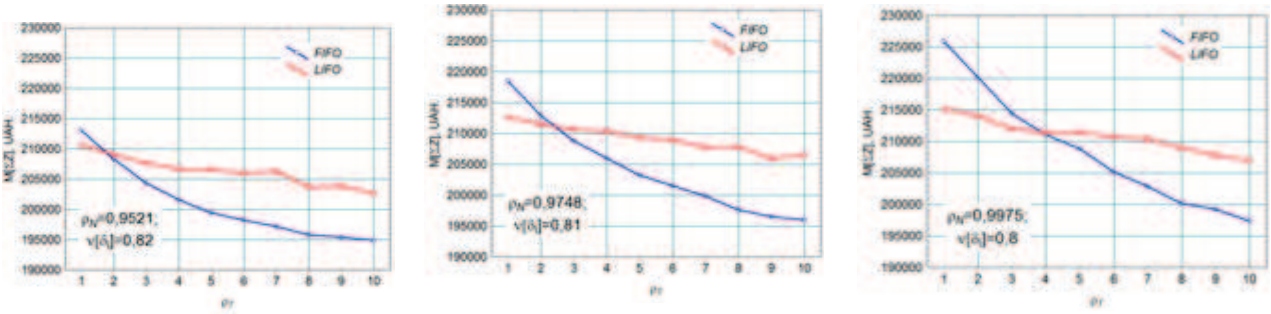

Fig. 7. Selection of the rational order of execution of orders for repair heads of cylinder blocks of YaMZ-236 engines for different values of temporal redundancy ρ_T different levels of batches of a repair service with productivity ρ_N.

When ρ_N = 0,9975, and the coefficient of variation of the daily batch of orders is only $\nu[\delta_i]$=0,8, which is corresponding to the last year of planned period of operation TD (T = 14), and direct sequence (FIFO) of repair orders performance is useful only if $\rho_T \geq 4$, and for minor repair warranty duration ($\rho_T < 4$) more rationally would to use reverse one (LIFO).

It should also be noted that in case of reduction of enterprise's orders capacity (in case of ρ_N decrease) direct order sequence fulfillment should be used for smaller values ρ_T. For example, if ρ_N=0,975 ($\nu[\delta_i]$=0,81), then direct sequencing is reasonable if TG = 3 days and nights($\rho_T \geq 3$), and for ρ_N=0,952 ($\nu[\delta_i]$=0,82) – already when TG = 2 days and nights ($\rho_T \geq 2$). If $\rho_N \leq 0{,}3$ direct and reverse order of execution of orders are equal for all ρ_T.

CONCLUSIONS

1. In the model of change of a year program of repair of heads of cylinder blocks of YaMZ-236 engines during the years, we obtained on the basis of technical service businesses data in Lviv region, that for its performance it is sufficient to use elementary TD production structure, where the number of basic technological repairing equipment of all types equals one. However, the level of congestion TD due to productivity in different years of TD operation fluctuate within a considerable measure ρ_N=0,09…0,9975 due to the variability of the annual program of repair.

2. The results of simulation modeling of batches process and service contracts for the repair of heads of cylinder blocks of engines YaMZ-236 we found out that both direct and reverse order of execution of orders with increasing ρ_N the value M[ξ_N] nonlinearly reduces, and the value of M[$\overline{\theta}$] conversely, non-linearly increases, reaching its extremes in ρ_N=1. Using a time reserve (increase of ρ_T) provides a nonlinear increase in the values of M[ξ_N] and nonlinear decrease of M[$\overline{\theta}$], however, more and more temporal redundancy is increasing the less change in M[ξ_N] and M[$\overline{\theta}$].

3. Analysis of the total costs of M[ΣZ] to repair heads of cylinder blocks, which include the actual cost of technological repairs Ztech and Z*sh* - costs of compensation for breach of warranty repair duration, showed that despite the considerable unevenness of the daily flow of orders in the range of values $\rho_N \in$[0,09…0,6] for all $\rho_T \in$[1…10] the value of fines Z*sh* is insignificant, and therefore $\Sigma Z \approx Z_{tech}$. With further increase of ρ_N the value M[ΣZ] increase significantly for all ρ_T by increasing the costs for compensation for customers Z*sh* failure of warranty repair duration TG, reaching its extreme value in cases where $\rho_N \to 1$. Using a time reserve (increase of ρ_T) provides non-linear decrease of M[ΣZ] values, however, more and more temporal redundancy increasingly lessens the change in M[ΣZ].

4. Based on the comparison of values M[ΣZ] for a different level of congestion of the selected TS which repairs heads of cylinder blocks YaMZ-236 engines, by productivity (different values ρ_N), we defined that in the condition $\rho_N \leq$0,3 direct (FIFO) and reverse (LIFO) order of execution of orders are equal for all ρ_T. In case when by the level of congestion TD productivity increases (in case of increase ρ_N), direct sequence (FIFO) of orders execution for repairs is useful only for more values of the reserve ρ_T, and for a small duration of the warranty repair TG it is reasonable to use a reversed (LIFO) order of execution of orders.

5. In order to minimize the total cost of repair heads of cylinder blocks YaMZ-236 engines we should consider increasing the duration of the warranty repair TG in those years of operation TS when the congestion level of productivity is very high. If it is impossible to change the terms of contracts with customers there, it is an urgent task of choosing the TS with a number of such parametric performance that will ensure the minimization of the total costs of repair ΣZ for the planned period of its exploitation.

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Researches of pneumatic sowing machine with peripheral cells location and inertial superfluous seeds extraction

Kateryna Vasylkovska, Olexiy Vasylkovskyy, Olexander Anisimov, Natalia Trykina

Kirovograd National Technical University, e-mail: vasilkovskaKV@ukr.net

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Abstract. In the article we provide the new design of pneumatic sowing machine with peripheral cells on the seed disk and a passive device for removing extra seeds with inertia method for precise seeding of cultivated crops. A series of studies was proposed for sugar beet seeds sowing device, we defined the influence of dilution in a vacuum chamber of sowing device and angular velocity cell seed disk on the cells filling factor. The design of the new pneumatic sowing machine can significantly reduce the vacuum in the system having increased the angular speed in cell seed disk to the values of seeding device travelling speed, thus provide a constant point of seeds drop from the seed disc at the same trajectory of their flight to the furrows and the qualitative cells filling. To determine the rational parameters and modes of sowing device we used method of multifactor experiment planning. We determined the main levels and intervals of varying factors for sugar beet sowing along with determining the filling factor of cell seed disk. With application of package Statistica 6.0. for parameter optimization - cell seed disk filling factor was constructed response surface and line of even output.

Key words: pneumatic seeding machine/device, seed disc, experiment, cells filling factor, dilution, cells angular speed

INTRODUCTION

Modern Ukraine - a country with high potential for the agricultural sector in the growing row crops, implementation of which is impossible without the introduction of new technologies and providing high-performance manufacturers of agricultural machinery. Selection of equipment for agricultural production in the initial phase, namely drills for precise seeding - is the primary condition for future good harvest.

Modern pneumatic sowing drill devices of high precision, despite a long history of their creation and improvement, have several disadvantages, the main ones are: insufficient dosing capacity caused by limited seed angular velocity of the disk ($V_k \leq 0,5$ m / s) and the presence of uncontrolled redistribution random intervals between the seeds in the furrow, because of the high relative speed of the seed in contact with the latter during the drills movement with nominal speeds (V_c = 1,5 ... 2,5 m/s). Eliminating these deficiencies is achieved by increasing the angular velocity of the sowing disk and its harmonization with the drills travelling speed. [1-5].

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

However, in the construction of modern pneumatic sowing machines to solve this problem is technologically impossible, since this affects the formation of one seed flow at an early stage of its formation.

The quality of seeds dosage to furrows depends primarily on the uniformity of seeds location on sowing disc. Therefore, the approach to choosing forms of the disc mouths is crucial initial condition of uniform dosage [6, 7].

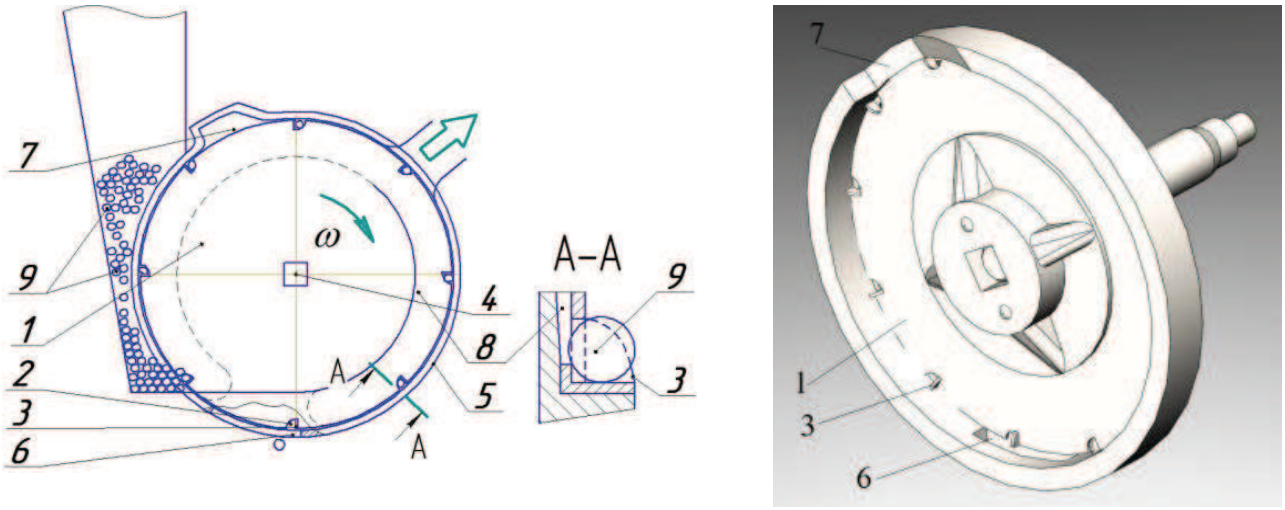
In order to improve accuracy at seeding process, at the Department of Agricultural Engineering of Kirovograd National Technical University we developed a prototype of a new section for accurate pneumatic sowing of cultivated crops seeds (Fig. 1) [1-4].

The main feature of the new sowing device is the presence of the original seed disc 1 with peripheral cells 2, where on its inner surface are placed blades 3 to force capture a seed in the chamber and its further transportation to the dumping area.

Seed disc 1 with cells 2 attached to the drive shaft 4 and inserted in a cylindrical cavity of the housing unit 5.

When rotating, the seed disc 1, the cells 2 with the blades 3 get into the seed layer, where under the forces of gravity and pressure of the grain, a seed is independently embedded in the cell seed disk. A capture of a seed is being done by the blade 3 at the first contact with a layer of seeds; the other seeds are pushing only one that is already in contact with a blade to cell 2, where we observe its secure grip and suction using airflow and reliable maintenance. Next the captured seed is moving with the disc.

The form of cell seed disk (Fig. 2) is performed with the expansion in the radial direction toward the stationary cylindrical surface of the frame, which closes their volume and creates a fixed outer wall from the filling to seeding zones. In the area of sowing on the surface of the cylindrical frame we made a seeding window 6, which opens the cell drives in this area and provides free seeds drop to furrows with help of the gravity and centrifugal forces.



a b

Fig. 1. The proposed pneumatic seeding machine: 1 – seed disc; 2 – cell; 3 – blade; 4 – drive shaft; 5 –the frame; 6 – seeding window; 7 – passive device for removing extra seeds; 8 – vacuum chamber; 9 – seeds a - the scheme; b – a three-dimensional model.

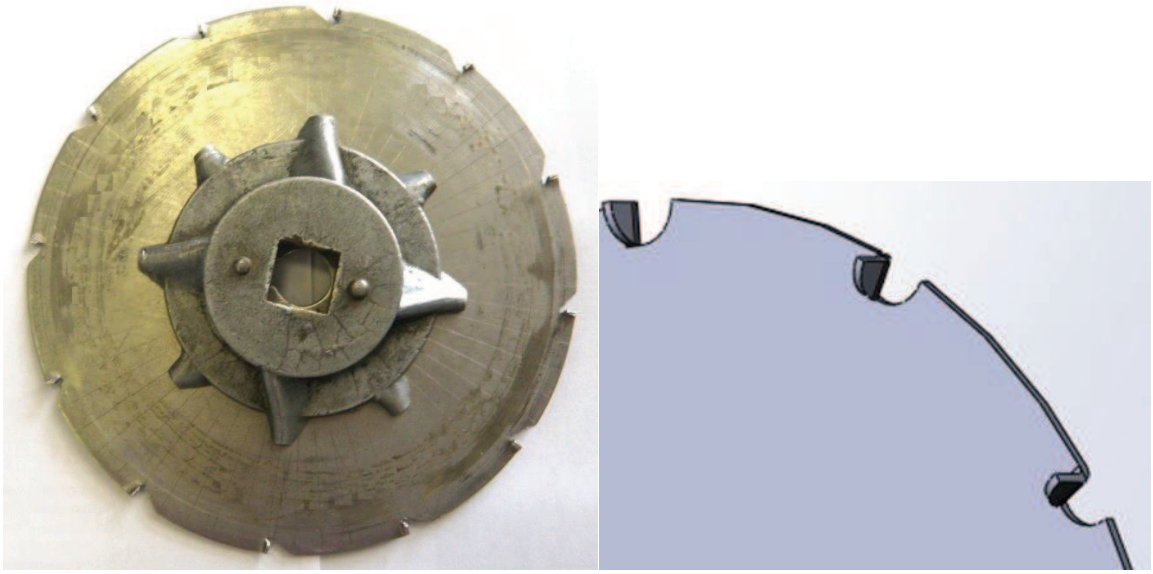


Fig. 2. General view and scheme of the sowing disc with a peripheral cells location.

In order to remove extra seeds from cell seed disk, next to it at the top of the cylindrical surface of the body, above the filling zone we made a passive device 7, which is a special cavity in which disengaging extra seeds are separated from the disk, and then fall (drop) in the filling zone of the working chamber.

The proposed improvement of the design of the pneumatic disc sowing device eliminates its major shortcomings, improves reliability and increases the process of cells seed disc filling as well as the efficiency of superfluous seeds removal and reliability of the cells exemption in the sowing area. This ensures a constant point of sowing seeds drop from the disk and the same trajectory of their fall to the furrows, which positively affects the uniformity of distribution and intervals between seeds in the furrow. This generally enhances the disk angular velocity and increases the productivity of the machine.

THE MAIN RESULTS OF THE RESEARCH

A series of preliminary and exploratory studies have shown [8-12], that the process of cells filling takes place at the time of seed layer entry into the cell of the working chamber.

This feature of the device as the availability of optimal conditions for seed orientation of the lower layer of seeds moving accordingly to the relative number of cells significantly improves their filling in a wide range of angular velocities and a small dilution in a vacuum chamber and does not require a large area of filling

Before the implementation of experimental studies we conducted randomization of experiments to level the influence of the factors that are not controlled, and to ensure their objectivity when choosing the object.

In order to determine the rational parameters and modes of the sowing device we used a method of multifactor experiment planning.

The purpose of the series of experiments has been the implementation of matrix 2^2 plan of Box-Hunter, in the result of which we determined the influence of the dilution effect in a vacuum chamber (ΔP) and the angular velocity of cell seed (V_a) on the quality of their filling.

Experiment planning of matrix presented in Table 1.

Table 1. Experiment planning matrix 2^2

№ of experiment	ΔP, kPa	V_a, m/s
	x_1	x_2
1	-1	-1
2	+1	-1
3	-1	+1
4	+1	+1

The seed sowing machine handy ability is easy to assess by the rate of filling cells, which is equal to the amount actually sown seed over time to the number of cells of the seed disk that have been gone the drop point over the same period.

The optimal distribution of seeds in a row can be achieved by filling the cells with no spaces. That is why as an optimization criterion we adopted the filling factor of cell seed disk.

The main level and intervals of varying factors for sowing sugar beet were determined by the filling factor of the cell seed disk (Table 2).

Table 2. Levels of factors in sugar beet seed sowing device of peripherally located cells to the seed disk

Factor	Natural denotations	Code denotations	Interval of varying	Levels of variation					
				natural			code		
				top	null	bottom	top	null	bottom
1	2	3	4	5	6	7	8	9	10
Dilution in vacuum chamber, *kPa*	ΔP	x_1	±0,2	0,5	0,3	0,1	+1	0	-1
Peripheral speed of cells, *m/s*	V_a	x_2	±0,5	2,5	2,0	1,5	+1	0	-1

In the first stage of experimental studies we used a disk with peripheral cells, whose number z is equal to 12 pieces.

Dilution in a vacuum chamber selected on the basis of studies [8-12], and considering the theoretical studies [6, 13, 14], according to which ΔR = 0.1; 0.5 kPa and in addition ΔR = 0.3 kPa.

The peripheral speed of cells V_p m / s was selected based on the recommendations of research, experiment results search [8-12], and the results of theoretical research according to which V_p = 1.5; 2.5 m / s and an additional V_p = 2 m / s [6, 13, 14].

Angle of opening of the passive device for removing extra seeds in the experiments was ε = 25 ° [13, 14].

So, we obtained the results of the experiment implementation of planning matrix (Table 3).

Table 3. The results of the experiment implementation of planning matrix 2^2

№ of experiment	Factors		Criterion
	Dilution in vacuum chamber; ΔP, kPa	Peripheral speed of cells of seed disc; V_p, m/s	Cells filling factor; K, %
	x_1	x_2	y_2
1	0,1	1,5	83,4
2	0,5	1,5	128,6
3	0,1	2,5	59,1
4	0,5	2,5	114,6

In the design of the experimental set its design was made adjustable for each parameter and was based on theory and previous studies which have impact on the seeding [8, 9, 11-13].

For processing the experimental data we used package STATISTICA 6.0 [15-16]. As a result, we conducted a construction of statistical mathematical model for the coefficient seed filling cells disk K, (Y_1 = K).

Statistical evaluation of the results allows to conclude that the experiments are equally accurate as the estimated value of the Cochran's Q test G^P for optimization parameter Y when n = 4 and f_u = 2 makes G^P = 0,478 and is less than the tabular value G^P = 0,7679 [17-20] therefore we conclude that the process is playing.

Dispersion reproducibility (error experiment) is 0.183.

So, we obtained the regression equations:

$$Y_1 = 96,425 + 25,175x_1 - 9,575x_2 + 2,575x_1x_2 \quad (1)$$

We constructed a response surface and a line of level output for filling factor of cell seed disk K (Fig. 3).

The analysis of response surface and the line of level output for optimal values of filling cells K, can determine the rational values of the investigated factors, namely:

– the value of rational dilution in a vacuum chamber $x1 \rightarrow \Delta P$, should be in the range of 0.20 to 0.30 kPa;

– rational peripheral speed of cells of seed disk $x2 \rightarrow V_p$ should be in the range from 2.0 to 2.5 m / s.

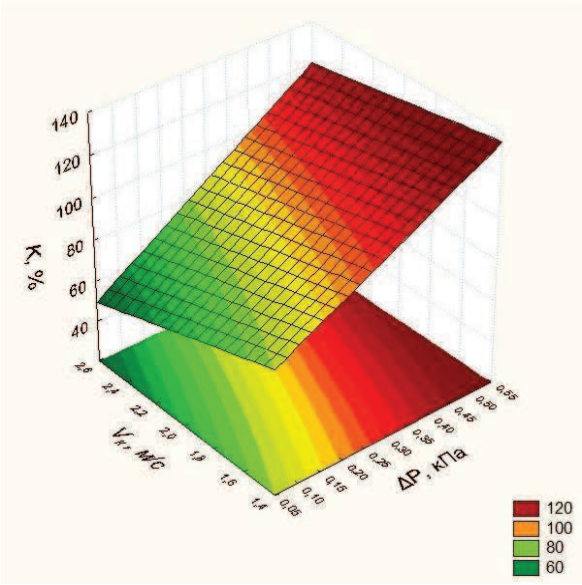


Fig. 3. The response surface and line of level output for cells filling factor of a seed disk.

The most influential factor in the process of filling cells seed disc of a research pneumatic sowing machine is the value of the dilution factor because in order to achieve a filling cell value K = 100% should be ΔP = 0,2 ... 0,3 kPa at the angular velocity of cells Va= 2.0 ... 2.5 m / s.

If we increase the value of dilution and reduct the angular velocity of cells we increase the filling factor due to worsening terms of dumping extra seeds.

CONCLUSIONS

The most influential factor in the process of filling cells seed disc of a research pneumatic sowing machine is the value of the dilution factor because in order to achieve a filling cell value K = 100% should be ΔP = 0,2 ... 0,3 kPa at the angular velocity of cells Va= 2.0 ... 2.5 m / s.

Thus, the design of the studied pneumatic device makes it possible to increase the angular velocity of the cells and reduce their number on the sowing disk, and greatly reduce the dilution in a vacuum chamber.

That is why the proposed seeding machine increases the technological efficiency of cultivated crops and reduces the energy costs.

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Simple expressions for the designing of the double bandpass optical filter

Oleg Kushnir

Lviv National Agrarian University, e-mail: o-p-ku@yandex.ua

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Abstract. Simple expressions for designing of the double bandpass optical filter have been obtained. These expressions make it possible to determine the phase thicknesses of the two symmetrical layers of multilayer structures, which provide double bandpass optical filter based on the interference reflector with an odd number of layers. The possibility of designing double bandpass optical filter with different bandwidth is shown.

Key words: bandpass optical filters, transmittance, multi-beam interference, antireflection, optical constants.

INTRODUCTION

The problem of creating effective interference coatings based on multilayer structures that could be used for making antireflaction coatings and optical filters [1-15] are solved for many decades. Double and triple bandpass optical filters are perspective for the use in medicine for diagnostics of different diseases. Also they were used in photolithography and in Raman spectroscopy [16,17]. Therefore one of the problems is remained by the search of simple methods of their designing.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Most narrowband filter design methods make it possible to obtain single bandpass optical filter. It used methods based on the calculation of equivalent refractive indices and phase thickness for combinations of symmetrical layers [18-20] and others. The problem of designing double bandpass optical filter is more difficult, as it is necessary to provide not only the appearance of two narrow bandpasses, but also the certain wavelength for them. A well-known method of designing double bandpass optical filter [21] based on the relatively difficult calculations of the phase thicknesses using special software. In another work [16] for double bandpass filter designing was proposed multilayer structure with only a quarter and half-wave layers, which narrows the possibility of the necessary wavelength selection for both bandpasses.

Simultaneous application of the conditions for zero [22] and high reflectance of the multilayer structure at normal incidence allows using them for designing of narrow bandpass filters [21]. These methods allow design filters with different bandwidth (including ultra-narrow) and the number of bandpasses (one or more) using only two different materials with high and low refractive indices, which can be chosen arbitrarily.

Uses of mathematically difficult antireflection conditions obtained for any transparent structure was a deficiency of these methods.

OBJECTIVES

The aim of this work is simplification of the expressions obtained before [23], for phase thicknesses of two symmetric layers that provide appearance of two bandpasses of the filter.

THE MAIN RESULTS OF THE RESEARCH

In previous work [21] the simple method of calculation of single bandpass optical filter was considered, got on the basis of multi-layered structure as an interference reflector with the even number of layers. For the designing of double bandpass optical filter for basis take the same structure, but with the odd number of layers. For the structure as an interference reflector with the indexes of refraction

$$n_0 - n_H - n_L - n_H - n_L - \cdots - n_H - n_L - n_H - n_{k+1}, \quad (1)$$

at that all layers are quarter-wave, except two symmetric with the numbers of s and m ($m = k+1-s$), antireflection is provided by determination of phase thicknesses these two layers with the help of the expressions [23]:

$$\tan\delta_s^{\pm} = \pm\sqrt{\frac{-N_s^2\Delta\Delta_m}{\Delta_s\Delta_{s,m}}}, \quad (2)$$

$$\tan\delta_m^{\pm} = \pm\sqrt{\frac{-N_m^2\Delta\Delta_s}{\Delta_m\Delta_{s,m}}}, \quad (3)$$

where: for the case of odd number $l = 2w+1$ of the layers whith phase thicknesses $\delta_{z_j} = \frac{\pi}{2}$ ($z_j \neq s,m$; $z_{j+1} > z_j$; $j = 1,2,...,l$),

$$\Delta = N_0 N_{k+1}\left(N_{z_2} N_{z_4} \ldots N_{z_{2w}}\right)^2 - -\left(N_{z_1} N_{z_3} \ldots N_{z_{2w+1}}\right)^2,$$

$$\Delta_s = N_0\left(N_{\varsigma_2} N_{\varsigma_4} \ldots N_{\varsigma_{2w+2}}\right)^2 - -N_{k+1}\left(N_{\varsigma_1} N_{\varsigma_3} \ldots N_{\varsigma_{2w+1}}\right)^2,$$

$$\Delta_m = N_0\left(N_{\xi_2} N_{\xi_4} \ldots N_{\xi_{2w+2}}\right)^2 - -N_{k+1}\left(N_{\xi_1} N_{\xi_3} \ldots N_{\xi_{2w+1}}\right)^2,$$

$$\Delta_{s,m} = N_0 N_{k+1}\left(N_{\rho_2} N_{\rho_4} \ldots N_{\rho_{2w+2}}\right)^2 - -\left(N_{\rho_1} N_{\rho_3} \ldots N_{\rho_{2w+3}}\right)^2,$$

and for the case of even l ($l = 2w$):

$$\Delta = N_0\left(N_{z_2} N_{z_4} \ldots N_{z_{2w}}\right)^2 - -N_{k+1}\left(N_{z_1} N_{z_3} \ldots N_{z_{2w-1}}\right)^2,$$

$$\Delta_s = N_0 N_{k+1}\left(N_{\varsigma_2} N_{\varsigma_4} \ldots N_{\varsigma_{2w}}\right)^2 - -\left(N_{\varsigma_1} N_{\varsigma_3} \ldots N_{\varsigma_{2w+1}}\right)^2,$$

$$\Delta_m = N_0 N_{k+1}\left(N_{\xi_2} N_{\xi_4} \ldots N_{\xi_{2w}}\right)^2 - -\left(N_{\xi_1} N_{\xi_3} \ldots N_{\xi_{2w+1}}\right)^2,$$

$$\Delta_{s,m} = N_0\left(N_{\rho_2} N_{\rho_4} \ldots N_{\rho_{2w+2}}\right)^2 - -N_{k+1}\left(N_{\rho_1} N_{\rho_3} \ldots N_{\rho_{2w+1}}\right)^2.$$

Here generalized refractive indices [10] $N_i = N_i^{\square} = \dfrac{\cos\beta_i}{n_i}$ for *p*-polarization and $N_i = N_i^{\perp} = n_i \cos\beta_i$ for *s*-polarization; numbers ς_u ($u = 1,2,\cdots,l+1$) include all numbers z_j and number *s*; numbers ξ_u include all numbers z_j and number *m*; and numbers ρ_x ($x = 1,2,\cdots,l+2$) include all numbers z_j and both numbers *s* and *m*. These numbers also have to satisfy the following conditions: $\varsigma_{u+1} > \varsigma_u$, $\xi_{u+1} > \xi_u$, $\rho_{x+1} > \rho_x$. These equations can be solved only for those structures, of which parameters satisfy the condition $\dfrac{\Delta\Delta_m}{\Delta_s \Delta_{s,m}} \le 0$.

In [23] equation (2), (3) were obtained for structures with arbitrary numbers *s* and *m* and arbitrary refractive indices of layers. For symmetric structures (1) and normal incidence $\Delta_m = -\Delta_s$ expressions (2), (3) become simpler even more:

$$\tan\delta_s^{\pm} = \arctan\left(\pm\sqrt{\frac{n_s^2\Delta}{\Delta_{s,m}}}\right), \quad (4)$$

$$\delta_m = \delta_s, \quad (5)$$

$$\Delta = n_0 n_{k+1} n_H^{\,k-2s+1} n_L^{\,2s-4} - n_H^{\,2s} n_L^{\,k-2s-1} \quad (6)$$

for even *s*,

$$\Delta = n_0 n_{k+1} n_H^{\,k-2s-1} n_L^{\,2s-2} - n_H^{\,2s-2} n_L^{\,k-2s+1} \quad (7)$$

for odd *s*,

$$\Delta_{s,m} = n_0 n_{k+1} n_L^{\,k-1} - n_H^{\,k+1}; \quad (8)$$

k is an odd number of layers for structure (1); n_0, n_{k+1}, n_H, n_L - accordingly indexes of refraction of environment, substrate, layers with high and low refractive indices; $n_s = n_m = n_H$ for the odd numbers *s* and *m* and $n_s = n_m = n_L$ for the even numbers *s* and *m*. Phase thicknesses, that satisfy equation (4) exist only for those structures in that $\dfrac{\Delta}{\Delta_{s,m}} > 0$.

For an example, we will consider a structure (1) that consists of 15 layers (*k*=15), in that a phase thicknesses of fifth and eleventh layers (*s*=5, *m*=11) we have to calculate. For such structure $n_s = n_m = n_H$, and expressions (3), (4) it is possible to simplify to the kind

$$\Delta = n_0 n_{k+1} n_H^4 n_L^8 - n_H^8 n_L^6, \quad (9)$$

$$\Delta_{s,m} = n_0 n_{k+1} n_L^{14} - n_H^{16}. \quad (10)$$

On the basis of the obtained simplified expressions (4), (5), (9), (10) were calculated phase thicknesses ($\delta_5 = \delta_{11} = 3.109$ *rad*) of the layers with the numbers *s*=5 and *m*=11 , when a structure (1) with the indexes of refraction $n_0 = n_{k+1} = 1$, $n_H = 4{,}3$, $n_L = 1{,}38$ becomes the double bandpass filter:

$$1 \mid (\mathrm{HL})^2\ 1.979\mathrm{H}\ L(\mathrm{HL})^2\ 1.979\mathrm{H}\ (\mathrm{LH})^2 \mid 1. \quad (11)$$

A characteristic property of this type of filter is that the choice of two different pairs of solutions (4) δ_s^+, δ_m^+ or δ_s^-, δ_m^- the position λ_0 of one bandpass does not change, and the position λ_0' of other one can be both at higher wavelength and at a lower (Fig.2) [21]. Namely, the choice of solutions δ_s^+, δ_m^+, provides the condition $\lambda_0' < \lambda_0$ and choices δ_s^-, δ_m^- provides condition $\lambda_0' > \lambda_0$. Another property of these filters is dependent bandwidth on the choice of numbers *s* and *m*. Besides the bandwidth of such filters decreases with layers addition (Fig.3).

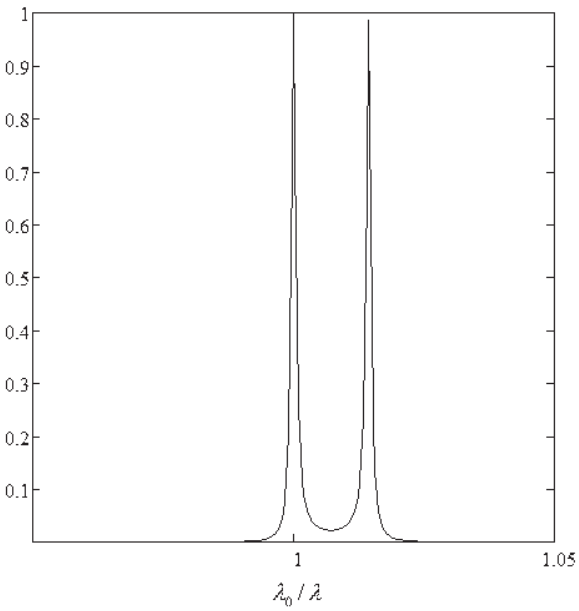

Fig. 1. Transmittance of the design with two narrow bandpasses $1 \mid (HL)^2\ 1.979H\ L(HL)^2\ 1.979H\ (LH)^2 \mid 1$.

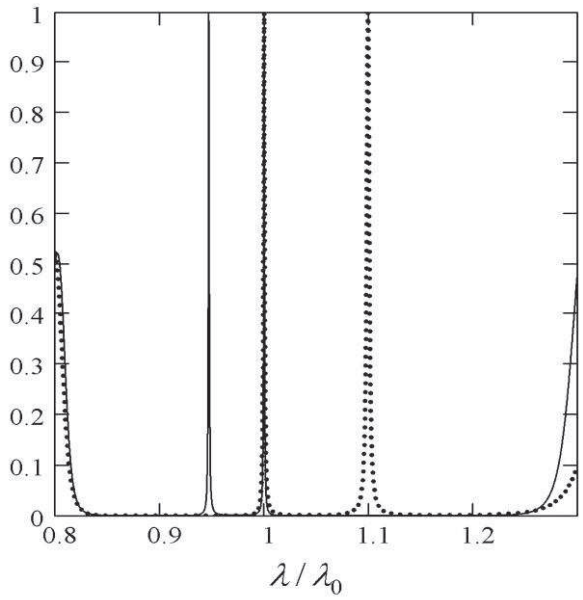

Fig. 2. Transmittance of the designs with two narrow bandpasses:

$1.52 \mid (HL)^5\ 0.1256H(LH)^2L\ 0.1256H(LH)^5 \mid 1.52$ з $n_H = 2.36$, $n_L = 1.38$ (dotted curve) and

$1.52 \mid (HL)^5\ 1.8744H(LH)^2L\ 1.8744H(LH)^5 \mid 1.52$ with $n_H = 2.16$, $n_L = 1.46$ (solid curve).

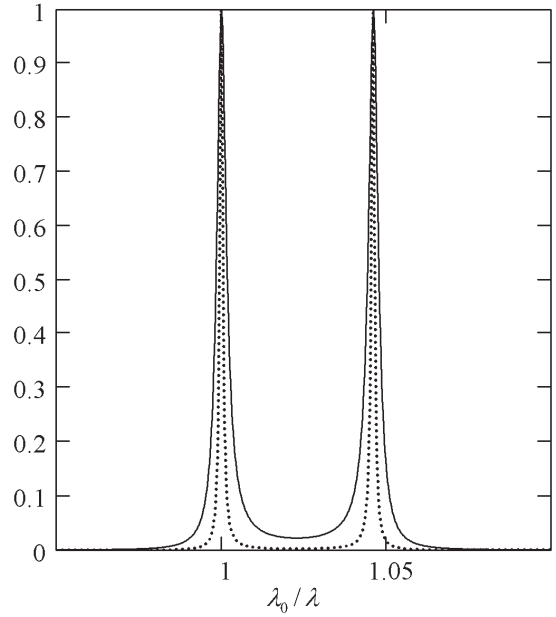

Fig. 3. Transmittance of the designs with two narrow bandpasses:

$1 \mid (HL)^2\ 1.9347H\ LHL\ 1.9347H\ (LH)^2 \mid 1$ (dotted curve), $1 \mid HLH\ 1.9348L\ HLH\ 1.9348L\ HLH \mid 1$ (solid curve) with $n_H = 4.3$, $n_L = 1.38$.

CONCLUSIONS

The simplified method of designing of a double bandpass optical filter with the uses of two different materials is proposed. This method is based on the calculation of phase thicknesses of two symmetric layers of structure (1) on the basis of the simple expressions (4) − (8) without matrix approach. Described method allows to get the filter with different bandwidth (including ultra-narrow).

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The relationship between the parameters of wind speed

Volodymyr Halchak, Serhiy Syrotyuk, Valery Syrotyuk

Lviv National Agrarian University, e-mail: ssyr@ukr.net

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Abstract. This paper analyzes the methods of mapping the velocity of wind flow, and using them to measure the performance of wind turbines. The dependencies of the two-parameter Weibull distribution function on the scale parameter are analyzed. It should be noted that the parameters of the distribution function, and therefore the repeatability are probabilistic.

The characteristics of Rayleigh distribution for different values of the scale are presented. The analytical-expressions and peculiar velocities of the integer and half-integer values for the shape parameters reflect the relationship between the mean, mean square, average-cubic, and estimated wind-speeds. It is shown that the ratio of the square of the average speed to the standard, regardless of the values of the shape-parameters and the scale-ratio can be replaced by the corresponding G-functions.The theoretical-calculation to design the medium-speed and its relation to the current and average speeds for the Weibull distribution with a half-integer values and the shape-parameter is presented.

It is proved that the recommendation considers the speed of the medium design to be proportional to the mean, and permissible only if the distribution is close to normal. It has been established that the ratio between average wind velocities (in the case of Weilbull distribution parameter) are determined only by its form and the average velocity through the scale parameter. Weibull distribution allows to facilitate and simplify their calculation methodology so as to assess the energy parameters of wind turbines.

Key words: wind, wind speed, distribution function, the mean values.

STATEMENT OF THE PROBLEM

The performance of wind turbines is usually estimated by the wind speed, which is determined experimentally from the established velocity distribution. However, only the average values of speed of a wind are given in literature [1, 2]. Both speed can be linked using the analytic dependence of the distribution function approximation - usually Weibull. Its parameters, in turn, can be reproduced, if the pre-estimated speed is sufficient for even a limited number of experimental data. However, the practical use of these dependencies is constrained due to the lack of a systematic presentation.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Separate equations for calculation of the average values of Weibull distribution, and their numerical values in some fixed-parameters of the form (k) and scale are reported in publications [3-11] and the expressions and graphic dependences given in [4-14], which involve the definition of the parameters k and distribution function measurements. They are borrowed from the European Atlas winds [15], and remain unpublished in Ukraine.

SUMMARY OF BASIC MATERIAL

Considering the nature of winds, measurement results are random variables, and their annual set form the general population. Irrespective of frequency rate of daily measurements, the results are treated according to the rules of mathematical statistics [3], and the calculated average values have a probabilistic sense.

In a data file of a total number N, individual results recur more often than others. If the full range of registered values are divided by the narrow intervals of equal width ΔV, then it is possible to find *Ni* results from each of them. For example, in case of hourly year-round measurements, n_i equals the total duration of a wind t_i in a predetermined interval of values when the total number of hours per year T = 8760. Hence the total number of hours during which the wind speed is recorded in a predetermined range of values is called repeatability. The first systematic measurements of wind speed at the meteorological stations of the European continent was performed only in the late 19th century, and results of the statistical processing is summarized in the work of Pomorceva [16], where it was shown that the frequency of winds has a probabilistic nature with the distribution of velocities close to normal. Subsequent studies have shown that the distribution of wind velocity is described predominantly by the asymmetrical distribution functions. Their numerical values or units are used to estimate repeatability - the total number of hours the wind-speed t_i within a specific range of $(V_i+\Delta V)$ during the

year, or probability of P_i. Both characteristics are connected by the following ratio:

$$\frac{t_i}{T} = \frac{n_i}{N} = P_i(V_i + \Delta V) \quad , \tag{1}$$

where: T = 8760 hours per year; n_i - number of measurements in every speed range; N - total number of measurements. Ideally, the number of measurements $N \to \infty$, and the width of the interval $\Delta V \to 0$. The probability for the width interval is called the probability density and is calculated as follows:

$$\Phi_i(V) = \lim_{\Delta V \to 0} \frac{P_i}{\Delta V_i} \cdot \tag{2}$$

For convenience sake's, the results of measurements were obtained using the probability-theory method, a number of experimental values $\Phi_i(V)$ at full range of speeds from 0 to $V_{\max}$ approximate functional dependency – usually a two-parameter Weibull distribution function:

$$\Phi(V) = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} \exp\left[-\left(\frac{V}{c}\right)^{k}\right] \quad , \tag{3}$$

where k – the shape parameter and c – the scale parameter.

Selection of these parameters agree with the experimental data parameters of the approximation function. A special case of the Weibull distribution with k = 2 is called the Rayleigh distribution, and for k = 1 - exponential. But for large values of k > 3, the Weibull distribution is close to a symmetric bell-close to normal (Fig. 1). The impact on the scale parameter distribution function is shown in Fig. 2 [4].

Approximate distribution functions allow to obtain analytical relations between such important practical average values:

- V_m – the probable speed at which the distribution function reaches its maximum;
- $\overline{V}$, V_{cp} – verage speed;
- $V_{ср.кв} = \sqrt{\overline{V^2}}$ – mean square speed;
- $V_д = \sqrt[3]{\overline{V^3}}$ – calculated speed;

$V_{опт}$ – optimal speed range wind turbines

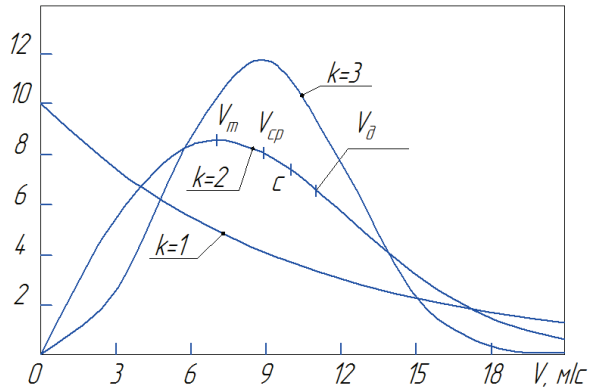

Fig. 1. Change in type two-parameter distribution function of wind speed at a constant value of the indicator scale c = 10.0 m /s and different form factor: k = 3 – Weibull; k = 2 –Rayleigh; k = 1 is exponential; V_{cp}= 8.86 m/s; V_m = 7.07 m/s; $V_д$ =11.1 m/s.

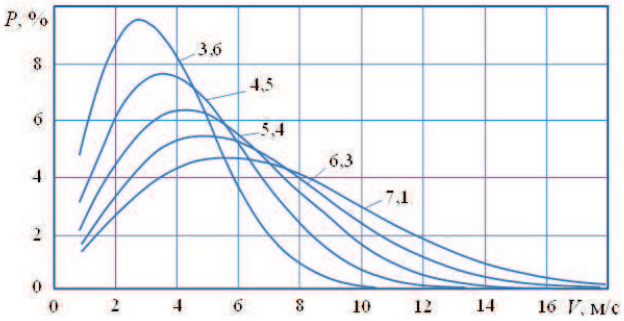

Fig. 2. Rayleigh distribution for different values of the scale parameter c.

Generally, in the case of an arbitrary value of the parameter k, the ratio for calculating the most probable velocities can be obtained using the rule for maximum distribution function and then equating to zero:

$$\left[\Phi(V)\right]' = \left\{\frac{k}{c}\left(\frac{V}{c}\right)^{k-1} \exp\left[-\left(\frac{V}{c}\right)^{k}\right]\right\}' =$$

$$= \frac{k}{c^2} \exp\left[-\left(\frac{V}{c}\right)^{k}\right] \cdot \left(\frac{V}{c}\right)^{k-2} \left[(k-1) - k\left(\frac{V}{c}\right)^{k}\right] = 0 \quad ,$$

where:

$$\left(\frac{V}{c}\right)^{k} = \frac{k-1}{k} \quad \text{or} \quad \frac{V}{c} = \left(\frac{k-1}{k}\right)^{\frac{1}{k}} . \tag{4}$$

The calculated values for most probable speed are expressed in terms of Weibull distributions parameter with several integer and half-integer values of the shape parameter k, placed in the first column of Table 1.

In the general case of arbitrary values of the exponent n, and the mean velocity distribution parameter k, the formula for calculating the average, mean square and root-mean-cube speeds can be obtained according to the rules of probability theory:

$$\overline{V^n} = \int_{0_n}^{\infty} V^n \Phi(V) dV = \int_{0_n}^{\infty} V^n \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} e^{-\left(\frac{V}{c}\right)^{k}} dV =$$

$$k\int_{0}^{\infty} V^{n-1}\left(\frac{V}{c}\right)^{k} e^{-\left(\frac{V}{c}\right)^{k}} dV \, . \tag{5}$$

Introducing the change:

$$\left(\frac{V}{c}\right)^{k} = U \; ; \; \left(\frac{V}{c}\right)^{n-1} = U^{\frac{n-1}{k}} ;$$

$$dU = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} dV \; ; \; dV = \frac{c}{k}(U)^{\frac{1-k}{k}} dU \cdot$$

Now

$$\overline{V^n} = k\int_0^\infty c^{n-1}U^{\frac{n-1}{k}}Ue^{-U}\frac{c}{k}U^{-1}U^{\frac{1}{k}}dU = c^n\int_0^\infty U^{\frac{n}{k}}e^{-U}dU .$$

If we take $z = n/k$, then the general solution of the equation (5) reduces to a calculation of the G-functions:

$$\overline{V^n} = c^n\Gamma\left(1+\frac{n}{k}\right) . \quad (6)$$

It is known that the G-function has analytical solutions for all integer and half-integer values of the argument (z + 1), and in the case of an arbitrary fraction, it is more appropriate to use the tabulated values given in reference [17]. When $n/k > 1$, the argument of G-function results into the standard form using this conversion:

$$\Gamma(z+1) = z\,\Gamma(z) = z!. \quad (7)$$

If the average speed indicator $n = 1$, then the arbitrary value k of equation (6) takes the form:

$$\bar{V} = c\Gamma(1+\frac{1}{k}) \quad (8)$$

The analytical and numerical ratios corresponding to the expression between the average speed and the scale parameter for five-functions of the Weibull distribution with integer and half-integer values of k-placed in the second column of Table 1.

Substituting n = 2 and n = 3 into equation (6) allow to obtain the expressions for calculating the mean square, root-mean-cube and calculated velocity V_∂ of speeds respectively:

$$\overline{V^2} = c^2\Gamma\left(1+\frac{2}{k}\right) . \quad (9)$$

$$\overline{V^3} = c^3\Gamma\left(1+\frac{3}{k}\right) . \quad (10)$$

Appropriate solutions for these average velocities relative to the parameter scale placed in fourth, fifth and sixth columns of Table 1. From Table 1, it can be seen within steady k that the ratio between the characteristic speed depends only on the scale parameter s. Therefore, the approximation expression for the experimental dependency of the Weibull distribution function is sufficient to determine at least two speeds, for example the average and the most probable.

Table 1. The analytical expressions and the value of special speeds for the whole and half-integer k

k	V_m	$\bar{V}$	$\overline{(V^2)}$	$\overline{(V^3)}$	V_∂
1	0	c	$2c^2$	$6c^3$	$1.817c$
1.5	$0.4807c$	$0.9033c$	$1.1911c^2$	$2c^3$	$1.260c$
2	0.7071c	$\frac{\sqrt{\pi}}{2}c$; $0.8862c$	c^2	$\frac{3\sqrt{\pi}}{4}c^3$; $1.3293c^3$	$1.099c$
2.5	$0.8152c$	$0.8873c$	$0.9314c^2$	$1.1018c^3$	$1.033c$
3	$0.8736c$	$0.8934c$	$0.9026c^2$	c^3	c

The European wind atlas recommends to determine the coefficients k and c function approximation using the following procedure. After grouping the results by speed intervals, the probability interval P_i from formula (1) is calculated, and then the sample values for the average and mean square speeds by the expressions:

$$\bar{V} = \sum_{i=1}^{N} V_i \cdot P_i ; \quad (11)$$

$$\overline{V^2} = \sqrt{\sum_{i=1}^{N} V_i^2 \cdot P_i} . \quad (12)$$

The ratio of the square of the average velocity to the mean square, regardless of the form k, and scale c, can be replaced by the ratio of the corresponding G-functions:

$$\frac{\bar{V}^2}{\overline{V^2}} = \frac{\left[c\Gamma\left(1+\frac{1}{k}\right)\right]^2}{c^2\Gamma\left(1+\frac{2}{k}\right)} = \frac{\Gamma^2\left(1+\frac{1}{k}\right)}{\Gamma\left(1+\frac{2}{k}\right)} . \quad (13)$$

Further selection of values of parameter k seem to best satisy the relations of G-functions for the pre-calculated ratio. After determining the scale parameter k is calculated according to one of the relations (8), (9) or (10).

This process for determining the parameters of the approximation function is rather cumbersome, therefore recommends the European Atlas of winds as the means for determining the values of graphic dependency of the speed-ratio as shown in Table 1:

$$k = f\left(\overline{V^2}/\overline{V^2}\right); \quad (14)$$

$$c/\overline{\upsilon} = f(k). \quad (15)$$

Both dependencies are shown in Fig. 3 and 4 using the table values of G-functions specified in the reference book [16].

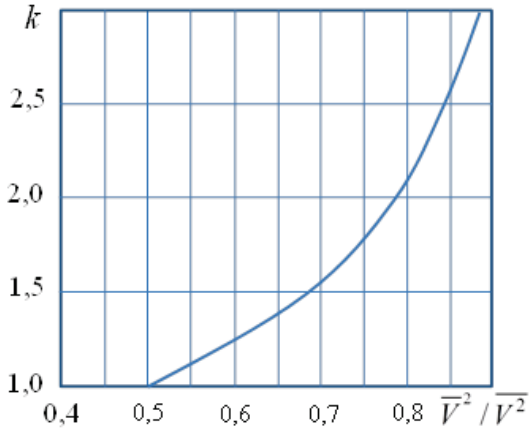

Fig. 3. Graphical dependence for determining the shape parameter of the Weibull distribution relative to $\overline{V^2}/\overline{V^2}$.

The experimental dependency rarely coincides totally with the determined-value of the approximate distribution function for two reasons, Firstly, the average value is not a ingle-valued function of a number of summation ($V_i\Phi_i$), and secondly - a two-parameter Weibull function does not account for random weather, seasonal or other deviations whose origins are impossible to be predicted.

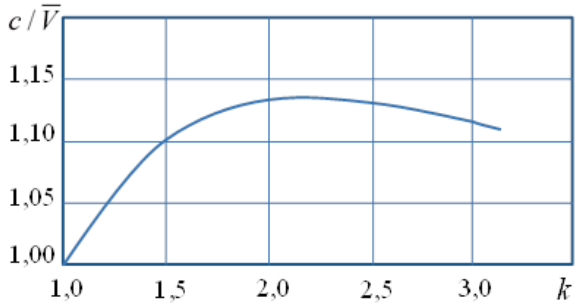

Fig. 4. The graphical dependence for determining the scale parameter of the relation $c/\overline{V}$.

It is known that the the performance of a wind turbine in Whr. at a constant wind velocity is estimated by the relationship:

$$W = C_p \frac{1}{2}\rho S(V^3 t), \quad (16)$$

where: S – section area of wind flow in m^2; ρ – air density in kg/m^3; Cp – the average utilization rate of energy flow; t – wind duration in hours.

But in any narrow interval for the duration of wind-speed in hours t_i, according to definition (1), is proportional to the value of the distribution function:

$$t_i = 8360\Phi(V_i). \quad (17)$$

Therefore, the annual performance of wind energy installation in any narrow speed range can write in terms of the distribution function as follows:

$$W_p = 4335 C_p \rho S V^3 \Phi(V). \quad (18)$$

The concept of wind energy uses the calculated (an estimated-average) speed V_{max} from which the maximum annual performance is realized. Its value corresponds to the maximum product $V^3\Phi(V)$, wherein, to simplify the operations of differentiation, we introduced replacement $V/c = U$:

$$c^3\left(\frac{V}{c}\right)^3 \cdot \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} \exp\left[-\left(\frac{V}{c}\right)^k\right] = c^2 k\left(\frac{V}{c}\right)^{k+2} \exp\left[-\left(\frac{V}{c}\right)^k\right] = c^2 k U^{k+} e^{-U^k} \quad (19)$$

Now:

$$\left(U^{k+2}e^{-U^k}\right)' = (k+2)U^{k+1}e^{-U^k} + U^{k+2}\cdot e^{-U^k}\cdot(-1)kU^{k-1} = e^{-U^k}\left[(k+2)U^{k+1} - kU^{2k+1}\right] = 0$$

$$\frac{k+2}{k} = U^k, \text{ or } U = \left(\frac{k+2}{k}\right)^{\frac{1}{k}} = \frac{V_{onm}}{c}. \quad (20)$$

According Tvaydellu [3], most of the distributions, based on experimental data, are well approximated by a two-parameter Weibull function with the values of the shape parameter k = 1.8 ... 2.3, and with a parameter, close to the average speed. In this range, the calculated value of the average speed is (1.28 ... 1.30) V_{cp}, and its relation to average almost linearly decreases with increasing k. Therefore, the recommendations in the works [18-20] validate the speed of the medium design to be proportional to the mean if the distribution is close to normal.

Results of calculation for the calculated average-speed, and and its relation to current and average speeds for the Weibull distribution with integer and half-integer values of the shape parameter are presented in Table. 2. The corresponding graphical dependencies are shown in Fig. 5.

Table 2. The optimum speed for distributions with integer and half-integer values of k

Parame-ter	k =1	k =1.5	k =2	k =2.5	k =3
V_{onm}	1.7321c	1.5275c	1.4142c	1.3416c	1.2910c
$V_{omn} / \overline{V}$	1.73	1.69	1.60	1.51	1.45
V_{onm} / V_o	0.95	1.21	1.29	1.30	1.29

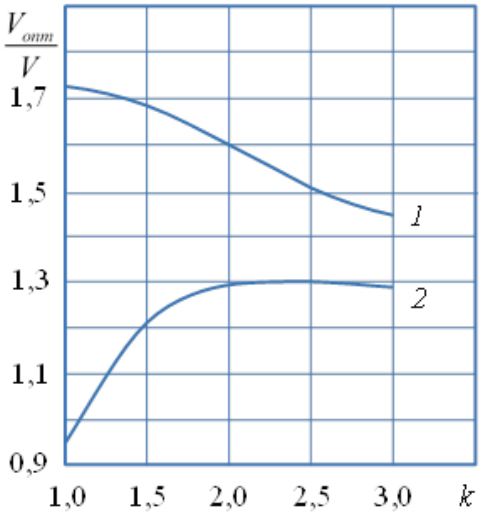

Fig. 5. The ratio between the mean-calculation and the average (1) and actual (2) wind speeds.

CONCLUSIONS

1. The relationship between average wind speed in the case of the Weibull distribution are determined only by its shape parameter k.

2. The presented average speeds through the scale parameter of the Weibull distribution facilitates and simplifies the calculation methodology for assessing the energy parameters of wind turbines.

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Technology readiness assessment in terms of financing reaserch and developement projects

Bożena Kaczmarska, Wacław Gierulski, Vasyl Lypchuk

Kielce University of Technology e-mail: bozena.kaczmarska@tu.kielce.pl

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Abstract. The methodology to assess technology readiness is currently the key instrument in supporting the decisions to finance research and development projects. It was originally used in the area of aviation and space technologies, where the requirements connected with reliability and resilience to extremely difficult conditions are very high. Nowadays the methodology is used in Poland in the evaluation of research and development activities related to commercial market that is characterized by massive diversity. The need to apply this methodology in the process of commercializing new products is indicated in this study.

Key words: Technology Readiness Levels, commercialization, innovation, product life cycle, financing research and development projects

INTRODUKCION

The main source of wealth of countries and nations comes from manufacturing in such a form that would allow us to find purchasers. This requires a constant search for new products that will replace those which are in the final stages of their life cycles.

RECENT RESEARCH AND PUBLICATIONS ANALYSIS

The studies presented in the literature refer mainly to the technical aspects of the TRL methodology [4, 5, 6, 7, 9, 11, 13, 15, 17, 18, 20, 21]. However, there are not many studies describing the TRL methodology in terms of commercialization of new products and their potential financing.

OBJECTIVE

The aim of the paper is to present the TRL methodology in terms of commercialization as well as the development of new technological solutions, and possibilities of obtaining funds from EU operational programmes.

MAIN PRESENTATION

Figure 1 shows the classic life cycle in terms of production engineering, considering the linkage with life cycles of previous and next products. This linkage makes it possible to raise finance for the development and introduction to the phase of growth and maturity of the subsequent products.

- Development- the idea for a new product is generated (sometimes it is an invention), its design and production technology is developed. The implementation capacity is analysed, prototypes that are to be analysed and evaluated are created. Production in terms of technology and organization is prepared.
- Introduction- the beginning of production, activities on improving the product and the manufacturing process. Measures aimed at improving the quality level, e.g. FMEA, control cards. Determining corrective actions, creating maintenance documentation. The beginning of work on developing the next product.
- Growth- increasing production capacity, minor changes to the product and manufacturing technology, strengthening and developing quality systems. The development of the service networks. The development and beginning of the phase of launching new product.

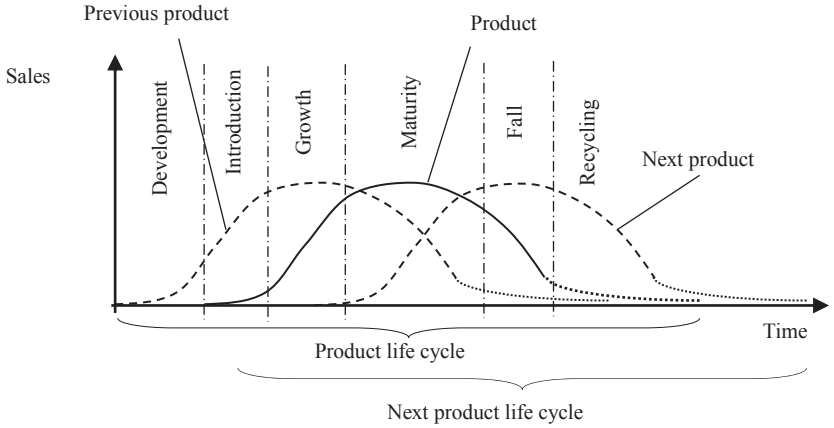

Fig. 1. Product life cycle
Source: [9, p. 8].

- Maturity- maintaining appropriate production capacity, changes and modifications of the product to increase its attractiveness. Effective use of quality systems. Launch and the phase of growth of the next product.
- Fall- maintaining the decreasing production, providing resources for carrying out maintenance tasks after the end of manufacturing the product. Gradual adjustment of manufacturing resources to manufacture other products. The maturity phase of the next product [9].
- Recycling- retirement and cassation, in which the waste product is separated into elements, and thus obtained materials are used again in different ways. Care for the environment often forces, already at the design stage, conducting LCA (*Life Cycle Assessment*), which involves the evaluation of the product impact on the environment throughout its entire life cycle including the use of resources in the processes of production, use and disposal.

Each subsequent implementation of the product life cycle is verified by the market at the interface of the seller and buyer. There occurs a relationship between them, which involves the point of interest "what" and the mode of operation "how" (Fig. 2).

The relationship on the part of the seller illustrates the issue of commercialization: what and how to launch on the market in order to sell. The answer to the question "what" is the beginning of the commercialization process and it is connected with the problem of innovations and innovation. The times when the land value, followed by coal, was the highest belong to the past. Nowadays it is knowledge and creativity that are the most valued, which leads to inventions and innovative solutions and is the only way to enter the path of rapid economic development.

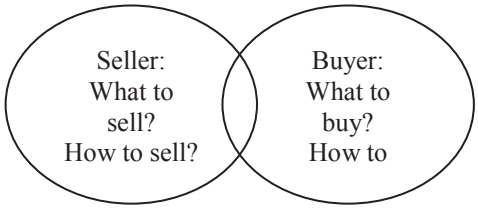

Fig. 2. The relationship between the seller and buyer
Source: [9, p. 10]

In these days of rapid development the answer to what to produce in order to be successful on the market is of particular significance. This may be a completely new product, or a currently manufactured product which has been altered. The transition from the stage "what" to "how" is a long process of launching. In this process called commercialization we can distinguish several basic stages, whose task-oriented illustration is in (Fig. 3).

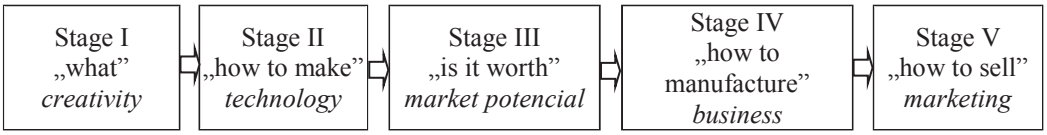

Fig. 3. Task-oriented commercialization process
Source: [9, p. 11-13]

Stage I – search for answers to the question: what to produce. Ideas are necessary, their generation requires creativity. Ideas originate thanks to creativity, however not all of them have the chance of reaching the end of the commercialization process. This is the most difficult stage, despite the fact that there exist various methods supporting the non-effective procedure of generating new ideas to ensure market success later.

Stage II – answers the question of technical feasibility of manufacturing the product. So this is a business area of engineering, without going into the details related to the design and technology. An overall assessment of the feasibility of the product is conducted, taking into account the expectations of potential customers. In a production environment unforeseen operating conditions [12, p.165] This stage requires the involvement of the designers, engineers and technologists in collaboration with marketing specialists.

Stage III – answers the question about business success, namely what has a decisive influence on the final decision about manufacturing a product or withdrawing from production. For that purpose the market potential is evaluated (otherwise known as the implementation or commercialization potential). The outcome of the evaluation supports the decision to continue or stop the commercialization process (Fig.4).

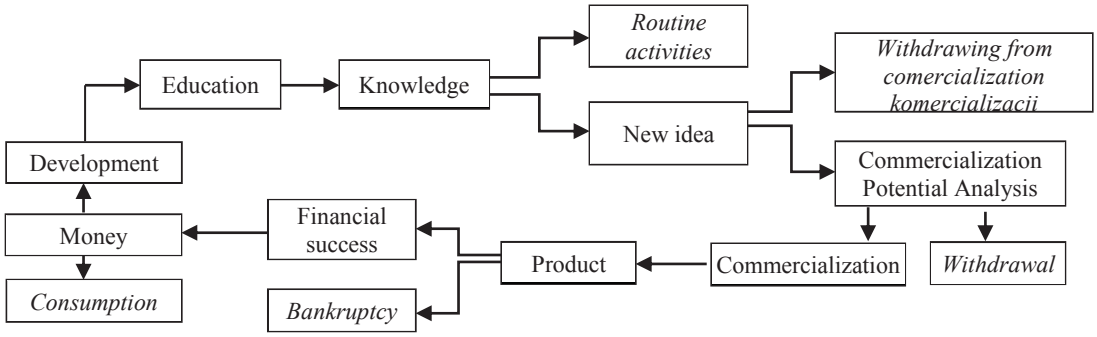

Fig. 4. Development loop: New idea - commercialization
Source: the authors' study based on [2, 13].

The loop indicates activities and events promoting or inhibiting the development process. The transition to new technologies requires significant costs associated with the upgrading of knowledge [3]. Education provides a man with knowledge that fosters creativity, which can be the source of new ideas. Learning can be formalized: in the form of school and higher education of the first, second and third degree, it can also be a non-formal process of learning.

Most knowledge is consumed for routine activities, while sometimes it effects in an innovative concept transformed into a new idea or invention, some of which are subject to commercialization. The decision of commercialization should be supported by an analysis of the commercialization potential. In contrast, the result of the commercialization process is the launch of a product. A sufficiently large number of sold new products leads to financial success.

Otherwise the commercialization process is not considered successful and can lead to bankruptcy. Financial success brings money which can be spent on consumption and development, closing the loop and starting a new cycle of learning combined with research and the emergence of new ideas.

Stage IV – is conducted after a positive decision about continuing the commercialization process and answers the question: how to manufacture the product. This is often implemented as a very large operation, whose aim is to prepare the production of new products. Nowadays this type of enterprise is carried out in the form of a project, taking into account the principles of project management.

This may be the classic PMBOK Guide methodology (A Guide to the Project Management Body of Knowledge), which contains a set of standards and solutions in project management, collected and published by the PMI (*Project Management Institute*) members [22]. It is a combination of activities in the field of engineering expertise and business operations.

Stage V – is associated exclusively with business knowledge, and it is based on marketing activities. At this stage it is necessary to identify potential markets for the new product and interest from prospective customers, as well as an indication of distribution channels.

The scheme illustrated in Figure 3 is consistent with the description presented by V.K. Jolly [8], who is considered the father and precursor of commercialization issues, and a frequently applied Cooper model. According to this description there are five stages in the process of commercialization, in which the subsequent stages were named and grouped in a slightly different way.

Finance plays a key role in the process of creating, developing and commercializing products. In many cases it is necessary to invest a lot of financial resources and lack of them or insufficient quantities are the main reason for resigning from commercialization or absence of final success. Financial needs grow rapidly in the subsequent stages of the commercialization process. It is assumed that the costs of stages II and III are at least ten times higher than the cost of stage I. On the other hand, the costs of stages IV and V are at least ten times higher than those of stages II and III. Figure 5 presents the distribution of costs depending on the stage of the commercialization process that is implemented.

Stage III is followed by a sharp increase in costs and the so-called „Death Valley" begins. The second slope of the valley is the end of stage V, when the marketing activities connected with the sale of a product are closed. The commercialization process comes to an end and costs associated with it decrease. At the same time there appear the first revenues from sales, corresponding to the growth phase.

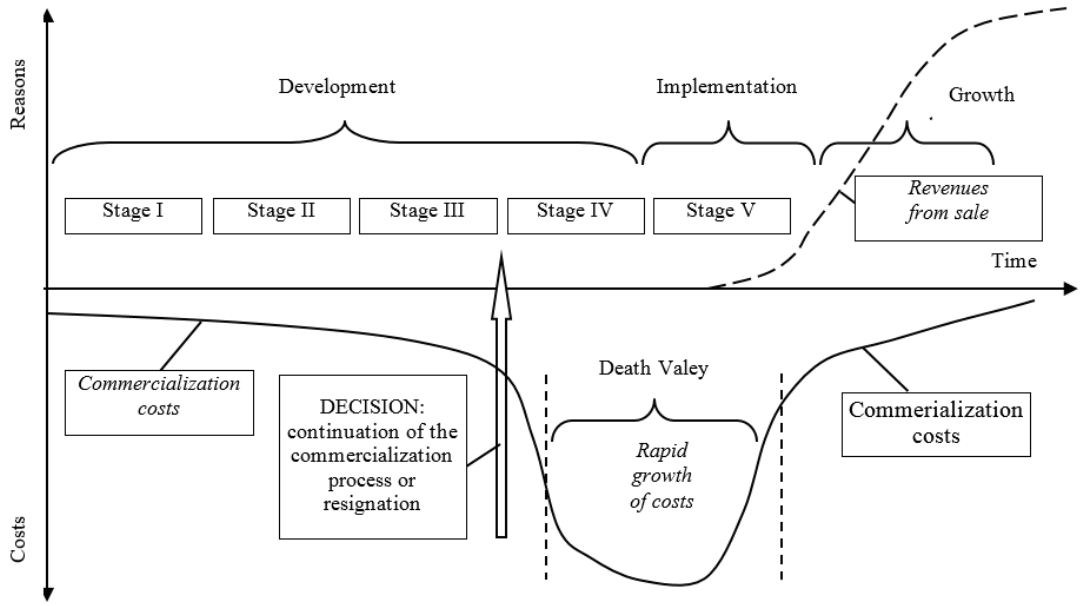

Fig. 5. Financial flows in the commercialization process
Source: the author's study

This rapid increase in costs causes numerous failures in the commercialization process. Therefore, before entering this stage the analysis of the commercialization potential, which takes into account the technical and business aspects, should determine the chances of success. The results of the analysis are the basis for making rational investment decisions. The assessment of the technology readiness may be a useful element in such an analysis in the part concerning the technical aspects.

Technology Readiness Levels are an instrument which makes it possible to determine the level of maturity of new technology showing innovative features. Technology is understood here as a manufacturing technique or as a product.

TRL constitutes a uniform metric used to analyse the status of work on technologies and their readiness for commercial implementation and is a key element in the assessment of investment projects relating to research and development [17]. The TRL methodology does not refer to the full process of commercialization, for example, it does not answer the question whether there is demand for the product or technology under assessment.

It is promoted as a tool for assessing research project co-financed by the European Union. For the practical application a certain scale was defined (Fig.6). The scale is represented by nine levels of technology readiness (Technology Readiness Levels) that are a reference model using a common measure, which makes it possible to assess the progress of work on new technologies. [15]

The TRL methodology was first used in R&D projects implemented by NASA and the US defense industry. According this methodology the maturity of technology is described from the phase of the idea of a specific solution (TRL 1), until the stage of maturity (TRL 9), when this idea as a result of research and development takes the form of a technological solution that can be applied in practice, e.g. by starting production and launching it on the market.

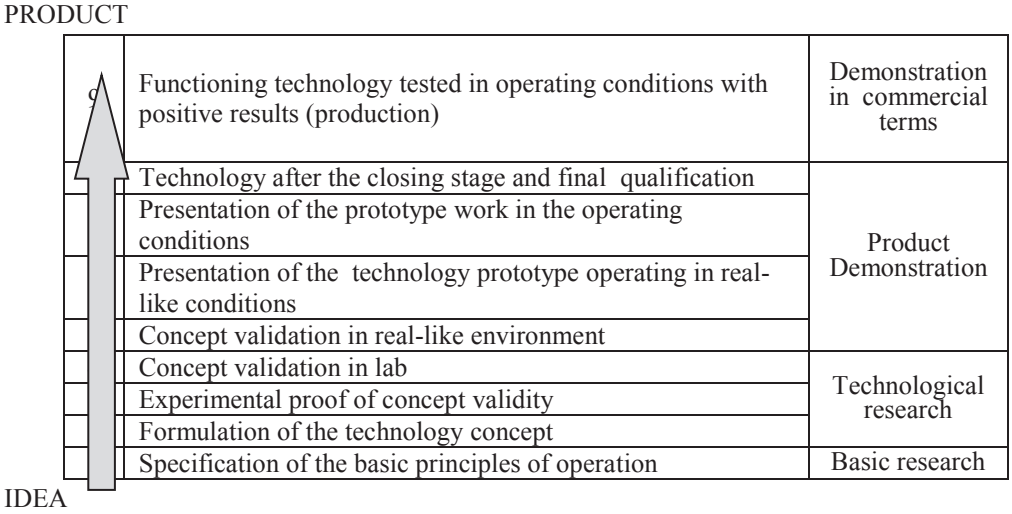

Fig. 6. Technology Readiness Levels
Source: the author's study based on [10 p. 108].

Currently, the TRL methodology is used in the assessment of research and development activities related to a commercial market characterized by a large diversity. This may result in a low efficiency assessment, especially in the absence of an explicit procedure of matching the current state to the levels indicated in the methodology.

This methodology is used by the Polish state organizations (e.g. National Centre for research and Development) in making decisions about subsidizing research programs.

The initial applications of the TRL methodology was aimed at assessing innovative designs related to technology transfer. However, there is no explicit reference only to the issues of innovation. This is partly due to the lack of commonly used tools and methods to assess innovation.

The so far applied binary assessment (innovative/non-innovative) does not account for the type of innovation, which makes the assessment difficult. This could be solved by applying a multi-stage scale of enterprise innovation level and by taking into account the technology readiness assessment applied by the enterprise and conducted according to the TRL methodology for evaluating the state of technology development [9,10].

There exist no unambiguous procedure of matching the current state with the levels indicated in the methodology, which may result in low efficiency of the assessment.

CONCLUSIONS

The methodology to assess technology readiness is currently the key instrument in supporting the decisions to finance research and development projects. Using one method requires taking into account the phases of the product life cycle process of commercialization of innovation funding. As the principal I can be used for assessment of TRL.

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Dynamic characteristics of perspective touristic information technologies

Olga Artemenko[1], Natalya Kunanec[2], Volodymyr Pasichnyk[2], Valeriya Savchuk[2]

[1]PHEE Bukovinian University; e-mail: olga.hapon@gmail.com
[2]Lviv Polytechnic National University; e-mail: valeriia.v.yehorova@lpnu.ua

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Abstract. The article is devoted to modern tendency and problems in the development of information technologies in the sphere of tourism. The aim of this paper is system analysis and identification of prospective areas of information technology in the field of tourism. The basic trends shaping the prospects for improvement in the information technology tools oriented to full and quality to meet the needs of ordinary tourists are consolidation of information resources in tourism; intellectualization of functions for software and applications, information technology and systems; interface virtualization environment for information systems, oriented to the needs of tourists; mobilization of tourists information technology support in the exercise of his trip; personalization tourist information needs, taking into account its specific individual requests tastes and preferences. All of them are analysed and described in the article. As a result author distinguished the main problems in the sphere of information technologies for tourist domain and main perspective spheres of next researches.

Key words: information technologies, tourism, consolidated information, mobile geographic information system, GIS, mobile tourist information technologies, trip support, interface virtualization environment, intellectual systems.

INTRODUCTION

Tourism is a very relevant business sector and plays a significant role in the global economy, accounting for a large part of world GDP. According to recent data, the annual growth of investment in the tourism industry is about 30% [1].

In recent years, the use of modern information technology (IT) systems have increased the pace of tourism development and most of the components of these systems have become successful e-business projects in their own right. Key participants in such projects are usually major airlines, hotels and tourist corporations on all continents. Information technology increases the efficiency and relevance of tourism services.

About two-thirds of the world's tourists use information technology to plan and support their journies, with most of them doing so on mobile devices [2]. Thereis an urgent need to create quality tourist information for mobile technology to assist the user in the planning, maintenance, support and analysis of travel experiences using one integrated mobile software and application.

The development of the tourism industry is interdependent on other related industries - usually transport, communications, trade, construction, agriculture and the promotion of the social and economic development of communities. To increase the awareness of tourists on the range of travel services offered by companies and organisations calls for the promotion of a consolidated information resource.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Researchers and developers are working proactively to create new tools and methods for the filing and processing of tourist information and they are designing intelligent systems to generate personalised recommendations. Powerful professional centtes of advanced mobile information technology for the tourism industry include The Digital Tourism Think Tank [3], the International Federation of IT and Travel & Tourism[4] and the University of Bournemouth (England) [5], Lugano (Switzerland) [6].

Baseing on an analysis of the extensive list of information sources, the authors concluded that existing information technologies that are focused on the needs of individual travellers do not provide them the full information support during the implementation of their travelling experiences [7].

It remains not fully worked out problems of consolidated information resources tourist profile, as well as their technological support using conceptual approaches to data warehousing, data spaces and big data. A separate topical issue in the field of information technologies in tourism is the lack of providing the user with personalized advice into account not only the wishes of tourists, but also his personal characteristics and circumstances.

Given the fact that most tourists traveling families or small groups, in the segment of modern IT there are not enough technological tools that would take into account the individual characteristics of travelers.

Theoretical and methodological framework and practical tools of information technology in the tourism business is covered in the papers S. Melnichenko [8]. In his articles Uhryn D. [10,11] the problems of data processing in tourism were analized and effectiveness of

their use in mass accumulation and processing of information and to consider improving the efficiency of tourism through the development of methods and algorithms for designing and modeling data objects space tourism industry.

N.B. Shakhovska outlined the concept of corporate data management technologies in the field of tourism [12]. However, the formation of consolidated information resource of tourism in their work is not considered.

Modern and particularly perspective IT in tourism gradually and inexorably developers are given signs of intelligence. This trend is common and comprehensive as the profile of information technology and algorithmic tools, and the functions that are increasingly receiving a greater extent characteristic features of "intelligence."

Another innovative trend of modern tourism IT is interface environment virtualization. Virtualization increasingly common as in the context of the process of formation and effective functioning of virtual travel agencies and business companies and in the context of building a system of virtual reality and reality with elements of GIS applications, including 3D image.

An outstanding is a trend of increasing popularity of mobile information technology focused on the needs of tourists, which in turn is due to the convenience and powerful functionality using mobile computing and communication devices by tourists during the planning and realization of the trip.

The analysis of the vast array of information sources can be argued that none of the currently existing mobile tourist information systems focus not fully meet the complex needs and requirements of all potential users. The authors initiated the development of intellectual information system of the next generation "mobile information assistants tourist" (MIAT) that satisfy a wide range of information needs of tourists in all stages of planning and implementation of his trip and will fill to a certain extent existing technological niches in the sector of information and technology market .

OBJECTIVES

The purpose of this paper is system analysis and identification of prospective areas of information technology in the field of tourism.

To achieve the goal, it was decided the following tasks:

• held alalizys of information sources on IT development in tourism;

• the necessity of the use of consolidated information in the field of tourism;

• formed the basic concepts of IT intellectualization tourism;

• analyzes the role of virtual companies in the field of tourism was provided;

• is defined prospects of development of fixed and mobile GIS oriented and needs of tourists.

THE MAIN RESULTS OF THE RESEARCH

An analysis of the vast array of scientific publications, reports and monographs were identified system features basic IT promising areas of research in the field of tourism.

The basic trends shaping the prospects for improvement in the information technology tools oriented to full and quality to meet the needs of ordinary tourists are:

• Consolidation of information resources in tourism;

• intellectualization of functions for software and applications, information technology and systems;

• interface virtualization environment for information systems, oriented to the needs of tourists;

• mobilization of tourists information technology support in the exercise of his journey;

• Personalization tourist information needs, taking into account its specific individual requests tastes and preferences.

Consolidated information in tourism.

Based on the interpretation of the term "consolidated information" as received from several sources and system integrated heterogeneous information resources together have signs of completeness, integrity, consistency and make adequate information subject area model for its analysis, processing and efficient use in decision making [9], the formation of such an information resource for the tourism industry is a reliable guarantee its effective functioning and steady progress.

Consolidated information resource occurs in several stages:

• search and data collection;

• pre-processing and structuring of data (data transformation to information);

• Analysis and synthesis of information - its transformation into knowledge;

• consolidation of information resources.

• developing a range of information products to meet the information needs of potential customers.

It should be noted that the procedures for the consolidation of information along with the procedures federalization form a complete set of methodological approaches to the problem of integration of information resources. This consolidation provides a deep and essential zintehrovanist information than the procedures federalization. Please note that the notion of "Consolidated Information" in many cases quite correctly identified with common in business circles concept of "competitive intelligence».

From the standpoint of information industry professionals of competitive intelligence as we treat legal implementation processes of selection, registration, processing and presentation of consolidated information about competitors and the competitive environment, the people who make decisions to improve business processes to reduce risk and improve efficiency of business systems. In our opinion, the accompanying definitions are essential and methodological and verified. Fixing it is this interpretation we:

a) defines competitive intelligence as a separate information activities with consolidated information resources;

b) determine who is a consumer of information resources as consolidated performance of specialists and competitive intelligence services;

c) defines the purpose of conducting competitive intelligence, namely reducing risks and increasing business efficiency and no fix possible types of risks and types of profiles and efficiency.

In this interpretation competitive intelligence is nothing more than a type of media consolidation and its outcome information is consolidated or consolidated information resource formed to ensure the correct management decision-making under risk and competitive environment.

Promoting implementation means consolidation of administrative functions is a mandatory attribute management processes. It is through the information component of a complex system, a type of tourism industry which is capable to interact purposefully with the environment, coordinate relations own components to direct their movement to the desired goal.

Consolidated information is formed using methods, means and methods, based on the information-analytical and system-analytical approach [14].

Development of analytical activities in the area of consolidation of information allows us to consider it as an independent branch information support, providing implementation and use of information technologies in enterprises and organizations.

Methodologically information and analytical activities to develop a consolidated information resources travel company that contributes to its development, is embedded in the following sequence of procedures: Search for available sources of information; analysis of information flows and data sets; the selection of relevant information that meets the needs of the organization; analytical and synthetic processing of information using new technologies; quality control and reliability of existing information resources; forming the system of archiving and preserving information; to provide potential customers with necessary information; organization of information resources management processes; monitoring and support of the security information in a computer system [16].

In today's business processes are gradually emerging understanding that the effective functioning of the tourism business not only material, financial and human resources. Priority should be given information component that ensures the creation of sustainable competitive advantage.

One way of improving the management of the enterprise in tourism is sustainable management of consolidated information resources. Creating a consolidated information in the tourism industry contributes to its economic potential and ensure effective use of sustainability.

Consolidated information resource of the tourism industry contributes to the problem of wider review of potential tourists from tourist attractions. Tourism development as a regional and local dimension is one of the main sources replenish the budgets of different levels [15]. In the context of the Galician region (Ukraine) it provides an affordable and complete rest and recreation of citizens, helps them to learn the history and culture.

Natural resources and historical and cultural potential of Galicia in combination with favorable geographical position is sufficient prerequisite for the effective development of tourism. For the region, in particular, is characterized tourists historical, cultural and architectural monuments, health and medical tourism. The main historical, cultural and architectural monuments in Lviv region as one of the elements systemnoutvoryuyuchyh territorial Galicia are: museum-reserve "Olesko", "Zolochiv castle" castle and other buildings, united in the "Golden Horseshoe" of Lviv region, reserve "Tustan" in s. Urich Skole region, literary-memorial museum of Ivan Franko - "Nahuievychi" in Drohobych district and others. The centers are Sacred tourism Univ, Krekhivsky monastery Stradchanska cave church and others.

However, the region's tourism industry has not yet developed the desired pace. One of the major reasons that inhibit these processes is the fragmentation of information on the tourist and recreational services. There is an urgent need to consolidate this information and formation on the basis of a powerful multifunctional content.

Formed for this purpose (for example, Lviv region (Galicia, Ukraine)) consolidated resource consists of oshyrnyh information on tourist facilities, provided in the relevant tables: castles, historic sites, recreational areas and places of pilgrimage and so on. Al. Improvement and development process of consolidation of information is closely related to access to information and market new technology developed that embody the concepts and knowledge databases, data warehouses (data marts and kiosks) [13], space data, large data that represent the current spectrum of integration of information technology.

One of the most powerful methods of information consolidation is kontent- monitoring, which allows forecasting and operational analysis of the market situation.

Content monitoring can be viewed as a classic adaptation of content - analysis of the terms of dynamic information files, including powerful information streams that are increasingly called big data (Big Data). This approach makes it possible to detect non-obvious patterns in data arrays or documentary texts, which are often referred to as latent (hidden) knowledge.

This allows you to create information products using the technology content - monitoring that is searching the "raw" data previously unknown hidden knowledge, providing a significant increase in the efficiency of decision-making.

A typical task in the process of consolidation of information, which is implemented using content - monitoring information is to find exceptions, ie search for information objects and entities that are allocated individual characteristics of the overall dataset.

Separating system features inherent in modern information technologies in tourism should be among the first to define the processes related to active use methodological basis of consolidated information. This trend of improving IT travel direction is dominant and comprehensive as equally successful when used as information support of the formation of objects of tourist infrastructure and the direct conduct of tourism business. Do not bypass this system trend information technologies oriented to the needs of ordinary tourists, including the

whole range of information technology services for its maintenance and support before, during and after exercise of tourist travel.

Advisory tourist guidance systems

One promising profiles improvement of tourism information systems are intellectualization of functions for software and applications. Note that in this context the rapidly emerging and developing original architectural approach to building Expert Systems Division, which is the advisory class (recommendation) systems for the tourism industry, particularly the route planner.

The analysis and comparison of the functionality of the four most popular mobile applications oriented route planning, the authors reviewed the methods and means of forming personal portrait Information / tourist profile, which are mainly implemented mechanisms inherent problem-oriented recommendation systems

Note that in this context the rapidly emerging and developing original architectural approach to building Expert Systems Division, which is the advisory class (recommendation) systems for the tourism industry, particularly the route planner.

Advisory (recommendation) system is an intelligent information system to form recommendations for the sequence and the list of possible user actions in the process of solving them specific problem task. Deliberative systems provide:

- online access to information resources and analytical services advisory system;
- support the formation and build-up of thematic databases and knowledge;
- consolidation and storage;
- full-text search of information;
- experts work on-line.

Powerful development and dissemination of recommendation systems, in addition to tourism, have been in business where used to improve interaction with customers, producing individual proposals that demonstrate best meet their requirements. The specific operation of original algorithms such as systems generally available to the public and trade secrets of companies that use them.

Recommendation systems can be used for filtering and selection of a wide range of necessary user information. This function extension of systems is becoming increasingly important given the growth rates of new information, leading to a significant complication of procedures for an integrated and systematic use.

When developing current recommendation systems are widely used research results from the fields of data mining and machine learning. The above issues intensively discussed by experts in the framework of the authoritative international scientific conferences, which are RecSys (recsys.acm.org), SIGIR (sigir.org), KDD (kdd.org).

Recommendation systems are becoming more common as advanced software algorithmic implementation of information technology designed to help the user to solve the problem of choosing the best, in his view, option among many alternatives. Use of recommendation systems in collaborative environments is important and allows for filtering of original algorithms that significantly improves the quality and efficiency recommendations.

There are examples of successful technological implementation of the concept of modern recommendation system for planning individual and group tourism itineraries, which, inter alia, in the decision taking procedures used parameters such as age, group size, gender, social structure and cultural level and profile members and others.

Tourism advisory systems have a broad range of approaches and methods of decision making. In particular, the analytic hierarchy process and utility functions, genetic algorithms, fuzzy decision semantic networks are utilized. The common feature tourism advisory system is a three-tier structure used models of decision making (Figure 1).

The first step is to establish the wishes of tourists every available model selection criteria. The characteristic feature of this type of intelligent information systems is the existence of the database, which contains an extensive list of possible recommendations. Recommendations are generally submitted a set of facts - values for selection criteria for a particular case. The next step is set correspondence between user-selected values and actual values for each of the database objects. In the third step is forming a list of recommendations for the best measures resemblance to the user's request.

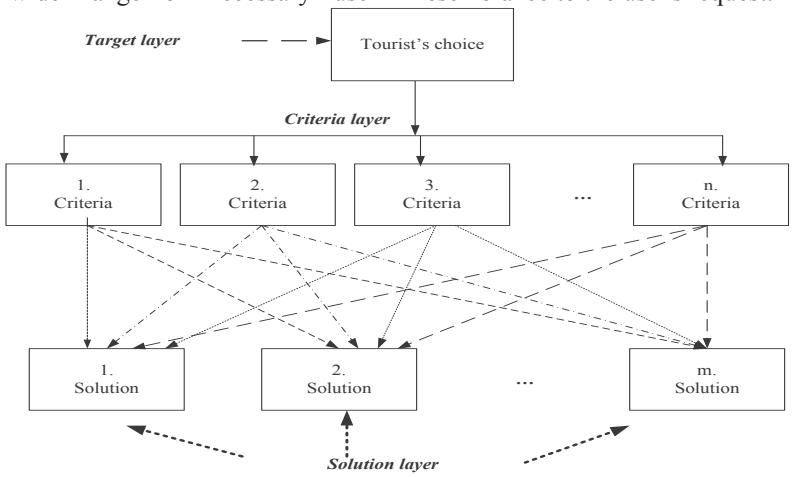

Fig. 1. The hierarchical structure of the travel advisory decision-making systems model.

E-tourism recommendation system as a specific class of intelligent information systems designed to provide offers to tourists at various stages of their journey. We know that the larger the number of available tourist options, make it more difficult choice. Tourist recommendation systems make it possible to provide technological support to guide decision-making in various subject areas.

There are systems that are focused on solving specific problems, such as selection of dining, housing, vehicles, historical monuments or popular tourist destinations. Others offer visitors comprehensive plans routes and trips that include multiple domains simultaneously.

There are several implementation of recommendation systems-oriented selection of proposals for a visit of a restaurant for the user. The study [17] presented data system Entrée, which recommended a particular restaurant using knowledge based approach. Knowledge Base system was formed according to the analysis of samples previously carried by the user: shearched analogies and associations of users in previous decisions on the criteria of "price" and "kind of cuisine."

Eventually Entrée was improved using the method of Collaborative filtering in the analysis of the knowledge base. This means that in addition to the customer's wishes and features a restaurant, estimates that users left after visiting recommended establishment also has a set of criteria for selection of potential options.

Another example of the tourism system is a mobile recommendation application designed to generate proposals for tourists visiting restaurants in Taipei (China) [18]. This information and technological development is a mobile recommendatory system that allows users to relevant proposals in real time, using Content-based recommender system.

CATIS [19] is recommendatory multitask system which generates a custom context-sensitive proposals for tourist accommodation, restaurants and attractions that may interest them. A feature of this system is the existence of a special dynamic manager who selects context information from the user's mobile device (eg, position and trajectory of the movement, history of requests, etc.). Recommendations are generated by combining the user's query parameters and analyzing contextual information about it.

Another analogue of recommendation information technology application for choice of dining is REJA (REstaurants of JAén), to implement a common approach which combines filtration and analysis of knowledge [20]. Recommendations can be provided using the common method of filtering when the system was able to build a profile in accordance with his requests and history using the application. When the system is not user information relevant recommendations generated using a knowledge base.

Personal tour planning system PSiS, created to help tourists in creating their individual plans excursions in Porto (Portugal) [21]. To avoid the shortcomings of many existing recommendation systems, including such which is the issue of the first evaluation, lack of data to create accurate user profile developers PSiS was proposed hybrid approach when forming the set of recommendations.

The proposed hybrid approach uses the methods of building recommendations based on collaborative filtering, content analysis algorithms in conjunction with clustering and build associative rules, as well as the application uses fuzzy logic to enhance the quality of recommendations.

Similarly constructed advisory information technology application SigTur [22] provides personalized recommendations for tourists in the region of Tarragona (Spain). To ensure high quality recommendations SigTur uses several types of information retrieval and recommendation methods. The information used in the application includes demographic data, contextual information journey location data.

SigTur combines a number of methods of generating recommendations, including using stereotypes (standard tourist segments), methods and means of artificial intelligence, including clustering algorithms, an ontology and knowledge base to identify new features of similarity between the users based on complex aggregation operators.

Mobile Recommendation System SMARTMUSEUM provides users with recommendations for attractions and some objects might tourist [23]. In the system used ontology approach to provide personalization, filtering and annotation information. Contextual data that has been entered by the user or obtained from sensors embedded mobile devices are displayed in terms specified in the relevant ontology.

iTravel - Mobile application used as recommendatory system was designed to provide recommendations for further tourist travel movement [24]. With the help of tourists who have common interests can share information and experiences about the places visited them in real time.

Moleskiing [26] - an information program-algorithmic product is designed to assist users active planning their winter holidays. He served as a recommendation system for users to exchange views and experiences on the terms and conditions of slopes and descents at specific resorts. This ranking system is supported by the credibility of comments and assessments received from specific users. Tourists wishing to go to the mountainous terrain, could use information about the weather conditions, as well as an assessment of how safe is one or another ski trail regarding their level of ski training.

DIETORECS [25] - a recommendation system that allows you to create a full itinerary of tourist travel. Depending on the wishes of tourists, you can get a list of attractions that may be of interest to the user, or variations of routes and tours covering such objects. Recommendation system for drivers MASTROCARONTE [27] using approaches based on the knowledge base for the development of recommendations on attractions, restaurants, and hotels. The application uses contextual information about the movement of the vehicle to form a convenient travel root for drivers.

The system SPETA [28] uses knowledge of the actual place of residence, history of its past locations and the range of his interests in order to further elaboration of recommendations route. It combines the functionality of social networks, semantic search the Web-space and contextual analysis to support the tourist information in the exercise of his trip.

Proposed in the study [29] algorithmic application allows the user to schedule so-called weekend tours and prolonged (over several days) tour.

Mobile tourism recommendation systems depend on the complexity of the tasks and requirements for submitting a speed of different methods of generating recommendations. To provide recommendations for relatively simple tasks such as the choice of a restaurant or hotel, are commonly used methods common filtering and / or analysis of user relevant content.

For developing of more complex recommendations, including proposals for the implementation of tourist routes and trips, the knowledge base and hybrid methods is used. Implementation of the recommendations in real time, for example for such tasks as finding the nearest petrol station, involves the use of methods and means of contextual analysis geoposicioning.

Virtual company in tourism, socio communications aspect.

Active deployment of modern electronic platforms in many business areas resulted in the need to create virtual organizations. Tourism industry is no exception. Create virtual companies travel profile against the background of the formation of large-scale distributed computing, communications, information infrastructure, which in turn is based on interdisciplinary approaches.

In this context, more obviously and naturally raises the problem of developing a new class of social communicational methods and tools, and related technologies that are based on them and are oriented to use in the efficient functioning of virtual organizations.

The authors analyzed the main social communicational problems and proposed original approaches to the formation of virtual agencies in tourism industry.

In the works of D. Zonnenwald an analysis of the concepts of organizational structures in the form of virtual organizations [30] and information exchange technologies features are presented [31]. In a number of publications [32-34] different ways of establishing communication in virtual settings are analyzed. Problems of development of virtual organizations are discussed in the article «Supporting Scientific Collaboration: Methods, Tools and Concepts» [35].

At the initial stage of the forming of methodological concept of virtual entities it is necessary to conduct a comprehensive research that would promote the development of social communicational technologies for individual, group communication of their employees, ensuring sharing of information resources, and effective and easy to use by different specialists of computer telecommunicational and algorithmic infrastructure.

The Formation of socio communicational technologies provides the development of distributed technologies for informational support of teamwork, working out the set of disparated diversed multiformat conceptual and analytical data, and overcoming language barriers and geodisperce of informational and communicational environment.

The implementation of the concept of a virtual company requires the formation and support of virtual team. Such groups usually bring together geographically or institutionally distributed workers that are specialists in different fields.

The concept of formation and effective functioning of virtual team is reinforced by appropriate architectural and technical solutions that contribute to the desired result. This generates a need for choice of partners, taking into account many factors, both subjective and objective nature [34] and necessarily based on competence approach, which is widespread in human resource management [36]. Competence is the ability of a combination of knowledge and skills to effectively perform clearly defined tasks.

When ranking the candidate to participate in the work of the group external factors that affect the determination of its compliance and can not be classified in a certain way, but only modeled for a particular situation are taken into account. An important role in determining the rating of the candidate plays his teamwork as an important requirement is his / her active cooperation with the team to achieve common business goals.

It is necessary to include specialist of IT industry in virtual teams for technological support of forming consolidated information resources, software development and technical support of computer and telecommunication tools that fully meet the needs of the company. This greatly facilitates the process of developing effective information technology systems and software, which together contributes to the maintenance of the virtual company if it is supposed to use huge databases.

The efficient operation of the company is ensured by rigorous analysis of information technology, suitable to meet the objectives of the company and information technology environment.

The development of virtual infrastructure for the operation of the company in the tourism industry usually occurs with the use of cloud computing technologies, which provide storage and access large volumes of data and knowledge.

An important issue in virtual-organized companies in general and tourism in particular, is to develop user-friendly interface and providr adaptive media communication staff, implemented on the basis of ontological representations relevant problem areas and situations.

Innovative technological challenges of a society based on knowledge, increasingly request form start a new trend of engineering, which the authors propose to call social communicational engineering. The process of designing and building virtual companies in the tourism industry undoubtedly belong to the scientific issues which would have to take care of it social communicational engineering. In order to form a holistic systemic interpretation of this concept and its terminology submissions propose the following definition of the

concept of "social communication". The necessity of such sequence is pointing definition of relevant concepts naturally stems from their structural and functional subordination of ontology in general subject area "Social communication". The term social communication we understand complex technologies, implementing the system of social interaction that provides communication processes of social institutions, organized communities and individuals.

The above definition of the term is original and somewhat different from the lengthy, often verified interpretations of the term "social communications" that are fixed in some terminological dictionaries.

Based on this formulation of the term the concept of "social engineering" can be defined as follows:

Social engineering is the science that studies and investigates the methods, means and ways of designing and constructing of elements, subsystems and systems of social communications in the Information Society, and later in the knowledge society.

With this understanding of a new kind of engineering we will submit a list of objects that are the subject of study and research of social engineering, in particular they are: social network; of e-governance; of e-science; of e-business; e-learning system; real and virtual social communicational communities; social institutions such as libraries, media archives and others.

Therefore, when creating a virtual company in the field of tourism it is advisable to used a wide range of social communicational methods and tools that ensure effective implementation of its functions with the use of modern computer and telecommunication technologies. Moreover, integration of information resources in these systems provides the use of the principles of consolidation and federalisation.

One successful example of this class of building is an international project that successfully operates in the structure of the Swiss Virtual Tour operator SwissHalley [37].

Geoinfarmation technologies oriented on the tourist.

In the tourism industry there are quite a lot of research and applied problems in the solution of which it is necessary to decide on the relative position of objects in space, routing, determining their length and complexity, optimal route selection etc. [38, 39]. Modern analysis of spatial distribution facilities is based on the use of geographic information technology (GIT). One of the promising areas of research is the application of GIT to tourist support tasks at all stages of his journey.

The main tasks that can be solved with the help of travel GIT are: creation of electronic versions of popular tourist destinations; locationing tourists, tourist facilities, vehicles, etc.; construction of a tourist route; maintenance of tourist travel; trip planning; virtual tourism, 3-D versions of tourist sites; thematic digital maps; dissemination of information on tourist facilities; analysis of tourist flows and spatial distribution of tourism resources; searching for diverse information in the field of tourism.

Different categories of tourists can use a variety of GIT at all stages of the trip:

- In preparation for the trip using GIT tourist can search data on facilities, trails, infrastructure; planning a trip and travel routes.
- When travelling with a mobile tourist application based on GIT it is available to use options such as location tracking, tourist facilities search, maintenance and adjustment of tourist route [39].
- After completion tourist travel GIT allows you to perform data analysis on tourist flows, the formation of reviews and evaluations, the exchange of experience (in many mobile applications are tools for creating voting and rating the quality of services, etc.) [38].

The leaders in the development of global GIS are now the products of two companies: these are system ArcGIS American firm ESRI and MapInfo – Corporation INTERGRAPH. Also, for the implementation of tourism GIT- applications GoogleMaps is often used [38]. To implement some specific tasks, such as virtual tourism created specialized GIS platforms, such as Cyber GIS [40].

Information technology decision support tools targeted to the specific needs of tourists and travel agents are developed and improved in the direction of mobile and web-based applications. The tools to solve the problem of personalization, optimization and maintenance of tourist during his stay on the route are among them.

The study [29] proposed an interesting algorithmic problem solving search for information on tourist resources and route planning. By user request are available spatial data on the location of social and tourist infrastructure, photographs and text information about places of interest and entertainment, as well as transport routes that take you to these places for a given initial position. The solution implemented in the form of application on Windows platform Visual Studio, export of geospatial data is GIS MapInfo. Information on tourist resources processed in the system in two modules: GIS geospatial data in the form of digital maps and additional information on resources in the form of metadata, access to which is realized through ADO components. The disadvantages of the proposed approach can be considered static presentation of data in the system and the lack of online access. Accordingly, the user has no possibility to carry out inquiries in real time and pave the way for the desired object from the current position.

Most mobile applications, travel guides and programs require the provision of tourist in space. The open question remains to determine the exact location of the tourist inside buildings, palaces, museums, historical or cultural complexes. To program guide automatically started and began the story of a particular memo or picture, you need to know not only exactly where it is a tourist, but also in which direction he is looking and where you want to move on. Find the external location of the user can be realized using GPS. Once is a famous tourist positioning of GPS, you can practically define the objects that the user is watching at any given time. However, there is no effective information technology for solving the problem of determining the coordinates of domestic tourist location as well as individual objects, such as inside a large museum. This would give an opportunity to develop a software solution in combination

with a program-guided, GPS-transmitter and GIS system, which offered to tourists - the owners of mobile personalized tour in real time [41].

The original solution to the problem and correcting laying route travel is a mobile application based on GIS and multi-agent system [42]. In application can be used geospatial information with commercial GIS formats such as ArcGIS and Mapinfo. Performing the transformation of geospatial data in GML, which makes it possible to ensure the flow of geospatial data to users of portable devices is freely without commercial plug-in software. The focus of the study, the authors focus on creating and implementing multi-agent system of choosing the best route. The algorithm is based on a multi-agent system at user-specified radius, specify factors to calculate the optimal path from one node to the target node map, given not only the length of the route, but traffic flow, the cost of commercial roads and other factors.

In the study [43] is shown the developed thematic digital maps containing information about hotels, guest houses, tourist routes, airports, railway stations, parks, churches, playgrounds, golf courses, hospitals, centres of ATM, restaurants, gas stations, police stations, water meters and entertainment facilities. Srinagar (India) for further integration with the web space to promote a tourist environment of information and assistance to potential tourists in the decision on travel itinerary respective regions, based on ArcGIS and Software ESRI 10.1. Digital maps, satellite images, GPS and statistics were used to create data layers above and were then combined with additional materials such as multimedia video clips, audio stories and photos. It is possible to develop web-based travel advisory information system that enables you to generate a number of answers to user queries on his / her trip to the city Srinagar:

- Where are the tour routs?
- What is the shortest way to reach a specific destination?
- What is the weather and geophysical situation of the destination?
- What is the best time of year to visit the city?
- What types and classes of accommodation are available, their cost, location, living conditions?
- Where are the important shopping centers, ATMs, parks, etc. Etc.?

The information system provides the user a number of tools to display the source data as a 3D maps, SQL-tables and queries.

The research [44] is devoted to the problem of getting personalized recommendations for tourists on daily excursion routes. The authors approach is that for pre-formed user list attractions that travelers like to visit, get the route for each day of the visit. The long journey is shares on separate days and formed a list of attractive tourist destinations which are grouped thematically or geographically distributed between these days. Places of possible interests are selected according to conventionally implied user preferences. The method allows the following: the individual planning of personalized daily tours based on user preferences, the time allotted for the tour, availability to visit monuments (schedule), the number of days of stay. This software application is available for web and mobile users.

Governments in countries with developed tourism markets ate interested in services creating to provide personalized information to tourists. For example, in Thailand a study intended to facilitate tourist in points of interest search and trip planning is performed. The application is designed in such a way that when filling relevant database it may be applied in other regions. The structure of the software modules is formed as an open architecture that allows other developers easily integrate it into the environment for relationship-oriented provision of other information technology services for tourists [45]. This development consists of three components: machine recommendation (PPR), route planner (IP) and mobile application (MTG). Together they form the basis for personalized travel planning system forThailand. PPR service provides a set of recommended for tourist sites and attractions (Points of interest - POI), corresponding to the user's interests. IP Service publishes a number of routes based on user requirements. Service MTG is actually a mobile interface that provides access to information on tourist services associated with the user's interests, its current location, travel time and others.

Planing the trip is formally regarded as a complex and time-consuming tasks that includes a variety of processes, ranging from finding specific tourism information on the country and accomodations of stay in it and completing the on spot planning of trip routes in unfamiliar areas. Information Technology Service provides the collection of data from various sources, including static and social, and further recomends the user points of interests (POI) and routes to pass the maximum number of POI, with maximum regard to his personal requirements and interests.

Trends that are traces in the markets of tourist information technologies, identify personalization and information-technological support of tourist at all stages of his / her journey, information and cognitive tourism thematization and adaptation to individual wishes of tourist and his/her financial opportunities.

From the above examples of modern developments in the field of tourism GIS applications, we can conclude that each of them is focused on solving of one or two problems that must be addressed to tourist during the trip. In addition, none of these applications does not provide IT support to the user at all stages of his journey. Another disadvantage of many developments is their "narrow" focus on separate resort area, city or tourist attraction [43,44].

Mobile information technologies for individual tourists.

Every tourist meets a large number of problems at all stages of the trip (before, during and after its implementation). He / she should always give answers to the question "Where?" "When?", "How?", "What?", Etc. [46]. The main aim of modern mobile information technologies in the sphere of tourism is to support the tourist during his trip any where and any time.

A group of researchers from the Lviv Polytechnic National University developed an innovative technological project of intelligent system "Mobile

Information Assistant of Tourist" (MIAT) in which a prototype of mobile integrated software and algorithmic complex of next-generation was worked out. Its basic functional purpose is to provide comprehensive information technology support to tourist at all stages of their travel. [47]

The project "Mobile Information Assistant of Tourist" is the development of innovative software and algorithmic complex based mobile computing and telecommunications.

In accordance with the objectives of the project following requirements for functional content of intellectual information system are formed: providing personalized information at any time, forming personalized routes with the possibility of changing it during the trip, assistance in choosing and reservation of transport and place of residence, location and navigation user during travel, travel budget calculation, generation trip costs report and a travel diary, the presence of off-line mode, providing tourist guide services (predictive maintenance) and augmented reality mode when user visits a particular tourist attraction [47].

The main feature of the system is to provide complete, accurate neprotyrechlyvoyi, consolidated information to the user in accordance with the basic information and technological slogan "EVERYTHING! HERE! IMMEDIATELY!!! ". Said intelligent information system should provide the necessary comprehensive tourist information support at any time and any where[47].

Functionality of the system is shown in Figure 2.

MIAT - is a complex structured software and algorithmic complex, requiring powerful hardware and software. Thus the main hardware of the client of the system is a mobile device with GPS antenna and the ability to connect to the Internet.

The main components of the intellectual information system are:

- Polls and preliminary analysis of results – this component is responsible for the users interviewing, formation of his/her account, recording gained data to the database of tourists and a general analysis of user responses with an aim to define general personality features of the tourist.
- Generation of recommendations for choosing a tourist destination – a component of decision support when choosing a certain tourist destination. The result of its operation is a personalized list of tourist destinations offered to a specific user. Recommendations are generated based on the survey and supported by information obtained from the Google Maps service.

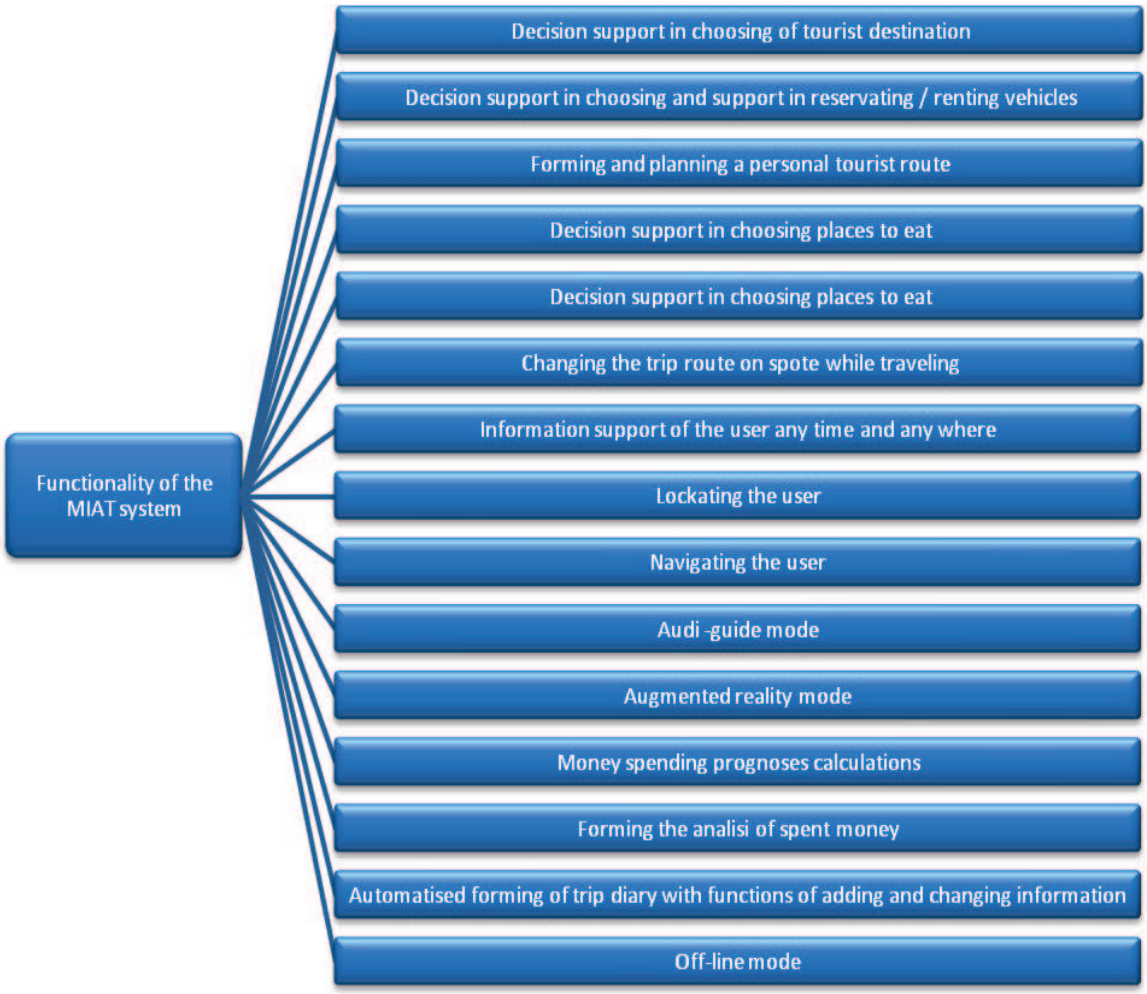

Fig. 2. The functionality of MIAT system.

• Route planning – this component has a complex structure and is responsible for a personalized selection of tourist facilities that are offered to the user to visit, their agreement with the tourists and planning optimal trip routes according to the wishes of the user, available budget and duration of the trip. An additional feature is the change of the tourist route during trip implementation, depending on the wishes of the current user and information about its location and providing personalized information about the places food.

• Reservations of accomodation and transport – this component is responsible for assistance in selecting accommodation for the user during his / her trip and transport decision-making. The reservation of selected places of residence and, where appropriate, transport are assumed.

• Selection of database data – a component that ensures the generation of necessary information on the direct request of the user, or to support the functioning of other dependent components.

• Navigation mode and "audio guide" – a component that provides a definition of the place of residence, users navigation on the tourist route and provide the user with information about tourist sites that are nearby. When the mode "audio guide" of the component is turned on, in addition to voice driving directions, the component provides detailed qualitative information about tourist points of interest that are in close proximity to the user in audio format. Without GPS, or connection to the Internet on a mobile device, the user will have the opportunity to inform the system about his / her current location.

• Augmented reality mode – a component that implements the operation of the augmented reality mode during a trip. What does it mean is: if there is a photo/video cameras in mobile devices, the component impose a label with information about further recommended direction of travel (using the data components of the "Navigation mode and" audio guide "), and with information about tourist sites that fall into the field of view of the camera of the users mobile device on the resulting image that is got with its camera in real-time.

• "Virtual tourism" mode – a component that is responsible for data acquisition of spherical images of tourist destinations, sending them to the components of the "Augmented reality mode" to be used instead of camera images received from mobile device. As a result, the user will be able to read the travel route planned on his / her mobile device.

• Calculating the budget – a system component that is responsible for the preliminary calculation of the indicative budget of the planned trip and forming the report of spent costs during its implementation. It uses data on the cost of accommodation, transport, food (offering the user to provide a report on the funds spent in catering establishments), entertainment and more.

• Formation of that travel diary – a component that is responsible for the preservation, sorting and description data during users trip, namely: passed route maps, photo and video files indicating heolokatsiy. An additional feature of the component is imaging the stored data sorted in ascending order of date of creation and divided by day to provide user-friendly viewing.

Google Maps is the chosen information sytem. The authors of this project selected this because of its powerful functionality and information content. Google Maps has a free map service supported by the company's technology. The service contains cartographic data and satellite images of the earth's surface and provides access to the integrated directory of"points of interest and maps of roads plus the Search function for routes [48].

According to research to implement MIAT the following resources will be needed: a mobile device with access to the Internet, a powerful GPS antenna and a server with a storage capacity of more than 1TB.

THE ANALISIS OF RESULTS OF THE RESEARCH

The rapid development of the tourism industry generates the need to include a growing number of researchers and developers to solve problems and develop effective modern information technology. After processing more than 1500 scientific publications on IT issues of tourism that were published over the last five years, a conclusion can be made about promising profiles in the tourist area of modern information technology and algorithmic tools that provide support and assistance to tourists during all stages of their journies, as well as the accompanying proceedings of the tourism business and its development.

These profiles and characteristics of current and prospective IT in tourism are:

• consolidation of information resources;
• intellectualisation of functions;
• interface virtualisation of the environment;
• mobilisation of information technology support
• Personalisation of information needs

Consolidation of information in the field of tourism hasn't yet gained full coverage in professional publications of the scientific achievements, although in many writings the conclusion that the consolidated powerful resource provides a significant and effective IT support industry development is traced.

It should be noted that the market for information technologies lacks tour GIS, which could equally be effective in information support and in accompanying tourists during the trip in different regions of the world. Based on the analysis the authors singled out a number of tasks which can and must be effectively and comprehensively implemented with the help of the instrumental algorithmic means of GIS. These include in particular: the choice of the tourist route; maintenance and tourist navigation on the route; adjustment of the route to the current location of the user and their chosen mode of transport; the optimal choice of transport (route number for public transport).

It is worth noting the topicality of establishing a system of integrated information support for tourists at all stages of their journies and that they should include:

• detailed information on tourist and other facilities

• thematic information about the type and characteristics of various infrastructure facilities (dining, accommodation, entertainment, service departments, etc)

- generation of a list of infrastructure facilities according to the tastes of the user
- augmented reality in the form of 3D-models of streets, buildings and other facilities
- the presence of additional information such as text, photo, video and audio materials in addition to digital maps.

CONCLUSIONS

The result of this research is the justification of basic features of the system and thedesign of an innovative intelligent information system: Mobile Assistant Tourist Information, oriented to support and assist the user in planning and implementation of tourist trips in accordance with the informational technological slogan: EVERYTHING! HERE! IMMEDIATELY!!! with mandatory compliance on convenience, comfort and privacy requirements while providing appropriate services and relevant information .

In turn, each of the examined system features of modern tourist IT is worthy of separate deep scientific analysis and professional research and the authors plan to conduct such analysis in the nearest future.

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