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ET
ARTIBUS

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11th INTERNATIONAL ACADEMIC CONFERENCE "COMPUTER SCIENCE & ENGINEERING 2019" (CSE-2019)

Decentralized Control Of Adaptive Measuring And Computing Processes Based On The Concept Of Balance

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Abstract – A method of decentralized control of adaptive measuring and computing processes in autonomous distributed systems based on the concept of balance and and reinforcement learning by the method of normalized exponential function (softmax) has been developed. The method allows one to organize autonomous distributed exploration under the conditions of dynamic changes in the number of measuring and computing processes and unreliable local information interaction between them.

Keywords – autonomous distributed system, adaptive measuring and computing process, concept of balance.

Introduction

The paper considers the topical issue of using multi-agent systems technologies [1,2] and machine learning methods, in particular reinforcement learning [3], to solve the problem of organizing adaptive measuring and computing processes (MC-processes) in autonomous distributed systems [4-8]. For this purpose the model of decentralized control of measuring and computing processes is developed based on the concept of balance, which is used to study the problem of coordinating joint collective actions from the point of view of finding an effective scheme for complementing the actions of individual measuring and computing processes in the absence of a control center.

The method of decentralized control of adaptive measuring and computing processes based on the concept of balance and reinforcement learning by the method of normalized exponential function (softmax) has been developed. The method allows one to organize autonomous distributed exploration under the conditions of dynamic changes in the number of measuring and computing processes and unreliable local information interaction between them. As a result of research and simulations, it has been established that the use of the method of the normalized exponential function provides a more effective search for a solution compared to the method of adaptive random search (by an average of 28.3%). Using the efficiency retention rate, an estimate was obtained for the dependence of the work of the developed decentralized control method on the change in the number of measuring and computing processes and the change in the information interaction scheme between measuring and computing processes.

The model of decentralized control of adaptive MC-processes

To study the problem of coordinating joint collective actions from the point of view of finding an effective scheme for complementing the actions of individual MC-processes in the absence of a control center, let us consider the following model of decentralized control of adaptive MC-processes based on the principle of balancing [9]:

$$M_D = < A, G(a,t), X, C, q(t)=f(F_q, \{x_t(a)\}_{N(t)}) >, \quad (1)$$

where $A=\{a\}_{N(t)}$ is the collective of MC-processes (agents) in the amount of N(t), which are located in some space X along the coordinates $\{x_t(a)\}_{N(t)}$, G(a,t) is a scheme of information interaction of MC-processes, C is a set of restrictions that are imposed on the coordinates of agents in the space X, q(t) is an indicator of the state of equilibrium and distance to it, such that

$$q(t) = \sum_{i=1}^{N(t)} (F_q - x_t(a_i)), \quad (2)$$

where F_q is the parameter of the equilibrium condition, the value of which is unknown to MC-processes. The collective of MC-processes is tasked with finding a location $\sigma(A)=\{x_t(a)\}_{N(t)}$ for which q(t)=0 (the value of q(t) or its sign is communicated to agents at each step, an agent can only change its own coordinate $x_t(a)$). Therefore, using the model M_D, the search for an effective scheme for complementing the actions of individual MC-processes in the course of solving a given problem is modeled as a search for the equilibrium state implementing the concept of balance. The search efficiency is defined as $w(T)=T_{min}/T$, where T is the time during which the collective found the equilibrium state, T_{min} is the minimum possible time to find the equilibrium state. The model allows one to study the influence of the dynamics of changes in the number of MC-processes N(t) and the parameters of the information interaction scheme G(a,t) on the collective search speed for the equilibrium state.

The method of decentralized control of adaptive MC-processes

Within the framework of the model M_D, a decentralized control method (DCM) for MC-processes has been developed. The convergence of MC-processes' actions is ensured by the use of the reinforcement learning method for stationary random environment, in particular the method of normalized exponential function (softmax). The DCM implements the following principles (Fig. 1): 1) the maximum step size $\Delta x_{max}(a)$ is proportional to the speed and magnitude of the change of q(t): $\Delta x_{max}(a)=f_v(\{q(t)\}_{\Delta t})$, 2) the action value $V_t(a,d)$ is modified according to the corresponding action values $\{V_t(a_i,d)\}_{K(t)}$, which at step t were obtained from other agents under the current condition of the information interaction G(a,t). According to the method of normalized exponential function, the next action $d\in\{-\Delta x_{max}(a),...,0,...\Delta x_{max}(a)\}$ is chosen with the probability

$$p_t(d)=\frac{e^{V_t(A,d)/\mu}}{\sum_{D_a} e^{V_t(A,b)/\mu}}\ , \tag{3}$$

where μ is the scaling factor (μ> 0, μ = const), and $V_t(a,d)$ is modified action value for the action d:

$$V_t(A,d)=\sum_{i=1}^{k(t)} w_i V_t(a_i,d)\ , \tag{4}$$

where $\{w_i\}_{k(t)}$ are weight coefficients such that

$$\sum_{i=1}^{k(t)} w_i = 1\ . \tag{5}$$

The local values of $V_t(a,d)$ change according to the obtained rewards r(t)=q(t)-q(t-1):

$$V_{t+1}(a,d)=V_t(a,d)+\alpha(r_t-V_t(a,d))\ , \tag{6}$$

where $\alpha\in(0,1]$ is learning step.

Simulation results

Simulation of the developed decentralized control method (DCM-softmax) showed its advantage over the adaptive random search method (ARS-0 - adaptive random search without information exchange, ARS-k - adaptive random search with information exchange, in which k is the number of neighbors, k < N) (Fig. 2, Fig. 3). On average, for various combinations of simulation parameters (X = {500, ..., 10000}, N (t) = {10, ..., 100}, k = {2, ..., 10}) DCM-softmax is better by 28.3% in the search efficiency w(T).

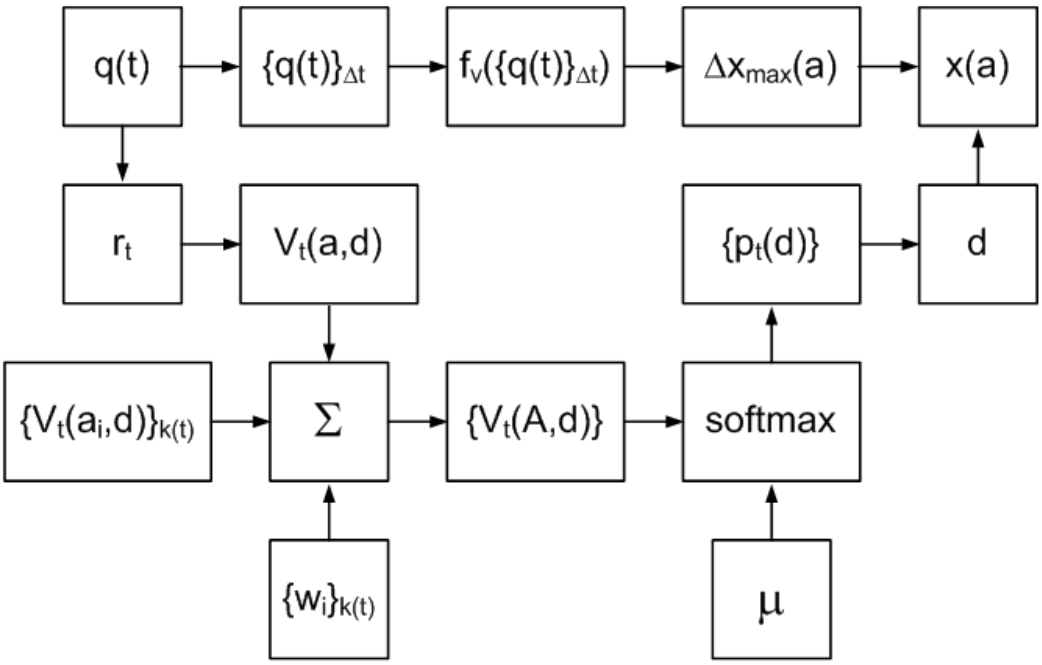

Fig. 1. The scheme of the decentralized control of MC-processes

Using the efficiency retention rate K_T, an estimate was obtained of the dependence of DCM-softmax on changes in the number of MC-processes (in the form of a stationary Poisson failure flow of MC-processes with a flow rate λ_a at the beginning) (Table 1) and changes in the information interaction scheme G(a,t) (in the form of a stationary Poisson flow of failures of communication channels between MC-processes with a flow rate λ_g at the beginning) (Table 2). The efficiency retention rates $K_T(\lambda_a)$ and $K_T(\lambda_g)$ were determined by simulating the operation of DCM-softmax. Here, $K_T(\lambda_a)=w(T)/w(T_n)$, where w(T) is the equilibrium search efficiency for failures at the first T_1 steps, and $w(T_n)$ is the nominal equilibrium search efficiency without failures at the first T_1 steps. According to the results obtained (Table 1, Table 2), DCM-softmax allows organizing autonomous distributed exploration under conditions of dynamic changes in the number of MC-processes and unreliable local information interaction between them.

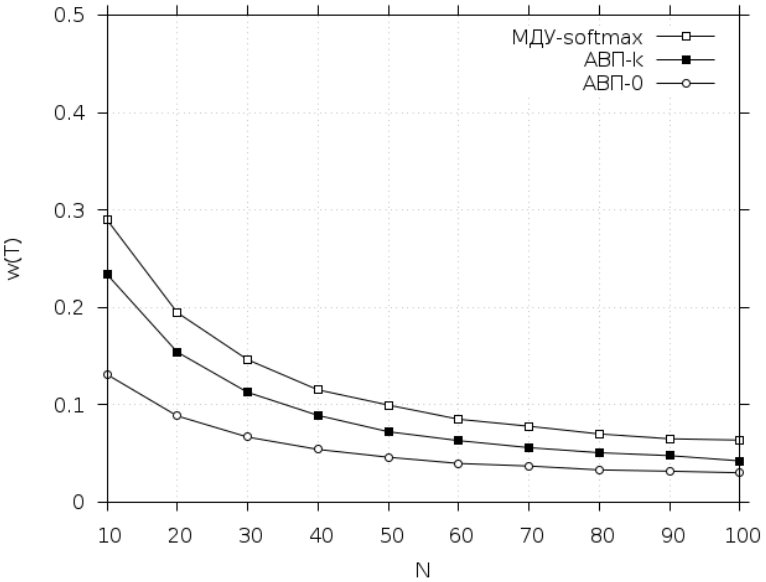

Fig. 2. Simulation results, X=1000, F_q=500, k=2, n=10000

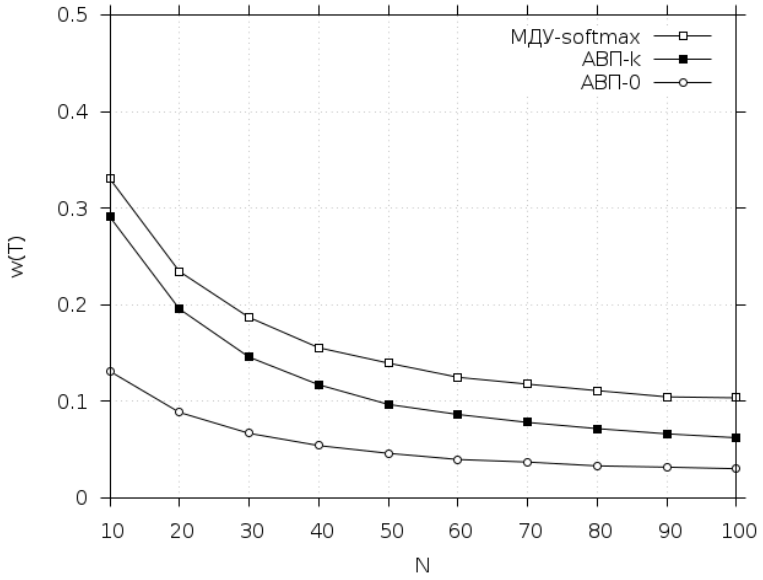

Fig.3. Simulation results, X=1000, F_q=500, k=10, n=10000

Table 1

Efficiency retention rate $K_T(\lambda_a)$, X=1000, F_q=500, N=50, k=2, T_1=100, T_2=1000, n=10000

	λ_a								
	0.005	0.010	0.015	0.020	0.025	0.030	0.035	0.040	0.045
ARS-0	0.765	0.485	0.334	0.245	0.197	0.156	0.181	0.135	0.115
ARS-k	0.798	0.509	0.367	0.276	0.221	0.185	0.165	0.140	0.128
DCM-softmax	0.841	0.590	0.459	0.385	0.331	0.301	0.281	0.261	0.247

Table 2

Efficiency retention rate $K_T(\lambda_g)$, X=1000, F_q=500, N=50, k=(N-1), T_1=100, T_2=1000, n=10000

	λ_g								
	0.005	0.010	0.015	0.020	0.025	0.030	0.035	0.040	0.045
ARS-k	0.796	0.510	0.362	0.279	0.228	0.186	0.164	0.140	0.126
DCM-softmax	0.867	0.612	0.480	0.404	0.355	0.319	0.303	0.283	0.272

Conclusion

A method of decentralized control of adaptive measuring and computing processes in autonomous distributed systems based on the concept of balance and and reinforcement learning by the method of normalized exponential function (softmax) has been developed. The method allows one to organize autonomous distributed exploration under the conditions of dynamic changes in the number of measuring and computing processes and unreliable local information interaction between them. As a result of research and simulations, it has been established that the use of the method of the normalized exponential function provides a more effective search for a solution compared to the method of adaptive random search (by an average of 28.3%).

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Strongly damped Stiff Oscillator under External Force: A Case Study

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Abstract – This is a numerical study of ODE systems modelling the dynamics of a strongly damped stiff oscillator under periodic force. After reviewing the notion of stiffness, we demonstrate and discuss convergence order reduction for some well-established numerical integrators. We also include some comments on stiffness in nonlinear systems.

Keywords – harmonic oscillator, stiffness, strong damping, numerical integration, order reduction, stiffness and nonlinearity

Introduction

Typical phenomena which are well known in the context of the numerical integration of initial values problems for ODEs are instability effects and reduced convergence orders when standard integration methods are applied to stiff problems. Originally, the term *stiffness* was introduced by G.Dahlquist (see for instance [4]); it means that general, transient solutions rapidly converge towards a quasi-stationary, smooth solution; this is asymptotically a very stable situation, but it poses a significant challenge for numerical integration. One of the earliest works on the effect of stiffness in numerical integration is [7], where scalar linear ODEs of first order were considered, and order reduction effects occurring in numerical methods were demonstrated. Apart from this effect, the scalar case is special in the sense that the difference between a transient and a smooth solution decays monotonously. Within the past decades, the theory of numerical integration of stiff problems has made significant progress, see for instance [5] and references therein.

A general stability and convergence analysis of numerical methods relies on particular a priori assumptions about the given problem. Consider for instance a model problem in form of a 2 x 2 linear ODE system

$$y'(t) = A \, . \, y(t),$$

where the real-valued matrix $A = A(\varepsilon)$ is diagonalizable, with eigenvalues $\xi = O(1) = \text{const.}$ and $\eta = \eta(\varepsilon) = -O(1/\varepsilon)$, with $0 < \varepsilon << 1$.

A rigorous and sharp estimate for the (worst-case) local growth of transient solutions $y(t)$, measured in the Euclidean norm $\| \cdot \|$, is given by ([5])

$$\| y(t) \| \leq \exp(\mu(A) \, t) \cdot \| y(0) \|,$$

where $\mu(A)$ denotes the so-called logarithmic norm of A, i.e., the right-most eigenvalue of the symmetric matrix $(A+A^*)/2$. (Here, A^* denotes the transpose of A.)

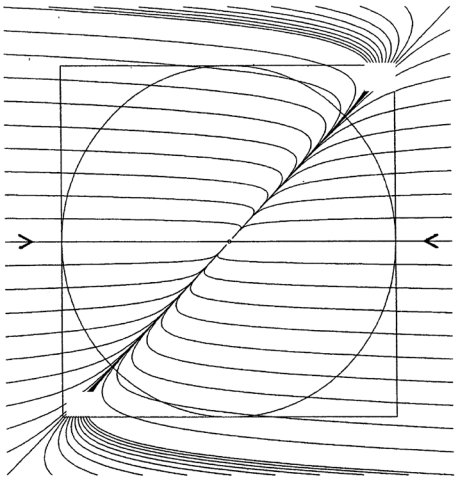

Fig. 1. Phase portrait of a stiff 2x2 system (cited from [2]).

In [2] it was shown that, in general. (note the + sign!)

$$\mu(A) = +O(1/\varepsilon) \quad \text{for} \quad \varepsilon \to 0,$$

if the matrix A is not normal (i.e., not symmetric,). Only for the symmetric case $A = A^*$ we have $\mu(A) = ((A+A^*)/2) = \xi = O(1)$ independent of ε. For a visualization of this effect see Fig. 1: Here, despite $\xi = 0$ we have $\mu(A) \gg 0$, and the norm $\| y(t) \|$ may grow locally very fast in the horizontal direction prior to damping, unless the eigendirections are orthogonal (which is equivalent to symmetry, $A = A^*$).

In the present paper we study a stiff linear model ODE system of a special type, involving what may be called an even more severe non-normality effect in the sense of [8] (see also [2]). In particular, the problem Eq. (1) resp. Eq. (4) considered below also has asymptotically stable solutions which also may locally grow very fast over small transient time intervals. For such a stiff model problem we study and compare the convergence behavior of two different standard second order integration methods.

Strongly Damped Stiff Oscillator

The dynamics of the time-dependent deflection $u(t)$ of a (free) damped harmonic oscillator with eigenfrequency $\omega > 0$ and damping parameter $\rho > 0$ is described by the second-order ordinary differential equation

$$u''(t) + 2\rho u'(t) + \omega^2 u(t) = 0 \quad (t > 0), \qquad (1)$$

subject to initial conditions

$$u(0) = a, \quad u'(0) = b. \qquad (2)$$

This is a simple model problem; however here we consider the case of a stiff oscillator subject to strong damping, i.e.,

$$\omega \gg 0, \quad \rho \gg 0, \qquad (3)$$

and we are interested in the performance of numerical integration methods applied to a system of such a type. We further assume that it is subject to an additional strong external periodic force. In

particular, we consider the 'most critical' case $\rho = \omega$, and consider as a test model the inhomogeneous linear second-order differential equation

$$u''(t) + 2\,\omega\,u'(t) + \omega^2\,(u(t) - \cos(t)) = 0. \qquad (4)$$

Remark: The choice $\rho = \omega$ simplifies some technicalities to follow; however this is not essential, and more generally, similar numerical effects as reported in the following are observed.

From an analytical point of view, the problem Eq. (4) is of course simple to understand. Asymptotically for $t \to \infty$, the solutions to Eq. (4) behave in a very stable way: All solutions $u(t)$ for arbitrary initial values given by Eq. (2) rapidly converge to a particular, 'damped-out', smooth solution

$$U(t) = (\omega/(\omega^2 + 1))^2\,.\,((\omega^2 - 1)\cos(t) + 2\,\omega\,\sin(t)), \qquad (5)$$

where $U(0) \in [0,1)$, and the limit of $U(t)$ for $t \to \infty$ is contained in the interval $[-(5+3\sqrt{3})/8,+(5+3\sqrt{3})/8]$. More precisely: Since $-\omega$ is a double root of the characteristic polynomial

$$\chi(\lambda) = \lambda^2 + 2\,\omega\,\lambda + \omega^2$$

of the homogeneous problem, the general solution to Eq. (4) is given by

$$u(t) = U(t) + c\,\exp(-\omega\,t) + d\,t\,\exp(-\omega\,t), \qquad (6)$$

where the constants c and d are uniquely determined in terms of the given initial values a and b from Eq. (2). The derivative of $u(t)$ is

$$u'(t) = U'(t) - c\,\omega\,\exp(-\omega\,t) + d\,(1 - \omega\,t)\exp(-\omega\,t). \qquad (7)$$

Note that for $d \neq 0$ the convergence of $u(t)$ towards $U(t)$ is not monotonic in general. In fact, what occurs is an effect called ‚hump', namely a transient growth locally near $t = 0$ prior to asymptotic damping. This means that, while the given system behaves asymptotically stable for $t \to \infty$, it locally behaves unstable, with a transient blow-up over small times. Fig. 2 shows a purely qualitative visualization of this effect.

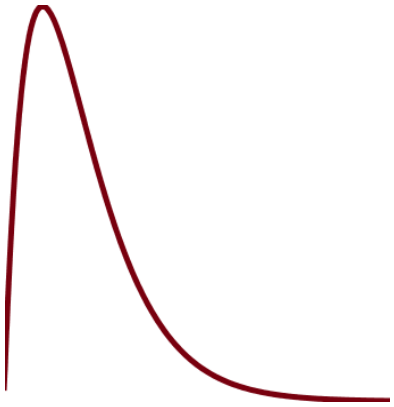

Fig. 2. The hump (cf. Fig. 1)

However we may ask what, in fact, is a natural measure for the growth or decay of solutions. In physical terms one may argue that for the homogeneous problem Eq. (1) a natural measure is

given by the total energy

$$E(u,u') = \sqrt{(\omega^2 u^2 + (u')^2)}, \qquad (8)$$

which is decreasing for increasing t, i.e.,

$$\mathrm{d}/\mathrm{d}t \; E(u(t),u'(t)) < 0,$$

see [1],[2].

Standard Numerical Integrators

(In the following we do not specify all details concerning standard numerical integration methods in detail, as this can be found in the standard literature as for instance [5].)

A problem of the type considered here shows a stiff behavior. As mentioned before, the existence of strongly transient and asymptotically damped solutions $u(t)$ poses a challenge for conventional methods like for instance explicit Runge-Kutta, because these methods behave in an unstable way and may not properly converge, even if the integration simply tries to follows a smooth, non-transient solution $U(t)$.

In principle, the remedy to this problem is well-known: For a stable numerical integration, appropriate *implicit* methods are necessarily required. 'Implicit' means that in each discrete integration step $t \to t + \Delta t$ with a given stepsize Δt, the new approximation for $u(t + \Delta t)$ is to be obtained by solving a system of implicit equations in terms of the previous approximation to $u(t)$, which requires some additional computational effort compared to straightforward explicit integration methods.

The simplest stable implicit integration schemes for stiff ODE systems of first order are the so-called Implicit Euler Scheme (IES) and the Implicit Midpoint Scheme (IMS), see e.g. [5]. We now are apply these schemes to problem Eq. (4). To this end we use a common transformation, namely defining

$$v = u' \qquad (9)$$

as a dependent variable, and we consider the equivalent two-dimensional first-order ODE system in the variables u and v,

$$\begin{aligned} u'(t) &= v(t), \\ v'(t) &= -\omega^2 u(t) - 2\,\omega\, v(t) + \omega^2 \cos(t). \end{aligned} \qquad (10)$$

The coefficient matrix A of this system is not diagonalizable, with a double negative eigenvalue $-\omega$. Nevertheless, its logarithmic norm is very large, namely

$$\mu(A) = +O(\omega^2) \text{ (!)} \quad \text{for } \omega \to \infty, \quad \text{see [1].}$$

In the classical, conventional sense, IES has an asymptotical convergence order $p = 1$, i.e., its global error is proportional to Δt for $\Delta t \to 0$. IMS has asymptotical convergence order $p = 2$, i.e., its error is proportional to $(\Delta t)^2$.

Another popular numerical method of convergence order $p = 2$ is the so-called 2-step Backward Differentiation Scheme (BDF2), a two-step generalization of IES, see [5].

All these methods are A-stable, i.e., they behave in a stable way for $t \to \infty$ when applied to an arbitrarily stiff scalar problem. In contrast to IMS, the BDF2 method is even strongly A-stable. (See [5] for a precise description of these notions of stability.)

Numerical Investigation of Problem from Eqs. (4), (10)

We now perform a numerical study of the IMS and BDF2 schemes applied to problem (10), where the parameter ω is chosen as $\omega = 1\text{E+}5$. In particular, we study the actual behavior of the approximation error in dependence of the stepsize Δt, starting at $U(0)$ from Eq. (5).

We stress that the fact that solutions of Eq. (4) or Eq. (10), respectively, show a transient behavior as visualized in Fig. 2 is the essential difficulty here.

Tables 1 and 2 show the results for both numerical methods considered. Problem Eq. (10) was integrated from $t = 0$ up to $t = 10$, first using 100 steps with $\Delta t = 0.1$, then using 200 steps with $\Delta t = 0.05$. The approximation errors at $t = 10$ in u, u', as well as in the energy $E(u,u')$ (see Eq. (8)) are specified together with the actual order p of the error observed on step halving from $\Delta t = 0.10$ to $\Delta t = 0.05$.

Table 1.

Numerical results for IMS

Δt	error in $\|u\|$	$\|$error in $u'\|$	error in energy
0.10	2.2E-3	4.8E+0	2.2E+2
0.05	4.9E-4 (p=2.2)	4.3E+0 (p=0.2)	4.9E+1 (p=2.2)

Table 2.

Numerical results for BDF2

Δt	error in $\|u\|$	$\|$error in $u'\|$	error in energy
0.10	3.2E-8	1.6E-3	3.6E-3
0.05	8.5E-9 (p=1.9)	4.3E-4 (p=1.9)	9.4E-4 (p=1.9)

From Tables 1 and 2 one can see that the convergence order in u and with respect to the energy norm $E(u,u')$ (see Eq. (8)) is $p \approx 2$. The strongly stable BDF2 method is much more accurate than IMS, by a factor approximately ω = 1E+5. Concerning u', the approximation quality provided by IMS is *stagnant:* The observed order p is close to 0, which is an extreme example of order reduction. Similar order reduction effects are also observed for higher order methods and other types of methods like for instance exponential integrators (see [6]), and also if these are applied to certain types of linear or nonlinear stiff ODE systems, as for instance Example from Eq. (11) below which we briefly discuss in the Appendix.

Appendix: A Nonlinear Stiff System

We conclude our discussion of stiffness effects by considering an example of a nonlinear system (sometimes called the '*Vienna problem*') which was considered in more detail in [9]:

$$\begin{aligned} u'(t) &= -v(t) - \lambda\, u(t)(1 - u^2(t) - v^2(t)), \\ v'(t) &= u(t) - \theta\, \lambda\, v(t)(1 - u^2(t) - v^2(t)). \end{aligned} \tag{11}$$

When the integration starts for $t = 0$ on the unit circle, i.e., with $u^2(0) + v^2(0) = 1$, then the resulting solution $(u(t),v(t))$ oscillates along the unit circle, with $u^2(t) + v^2(t) = 1$ for all t.

In Eq. (11), the parameter $\lambda << 0$ characterizes the degree of stiffness, while the (moderate-sized) parameter θ, if chosen as $\theta \neq 1$, causes an additional non-normality effect for the Jacobian of the system along the smooth solution. Fig. 3 shows a phase portrait of the general

behavior of solutions to Eq. (11). For preparing this visualization we have used the computer algebra system Maple ([10]); the problem parameters are chosen as $\lambda = -10$ and $\theta = 3$.

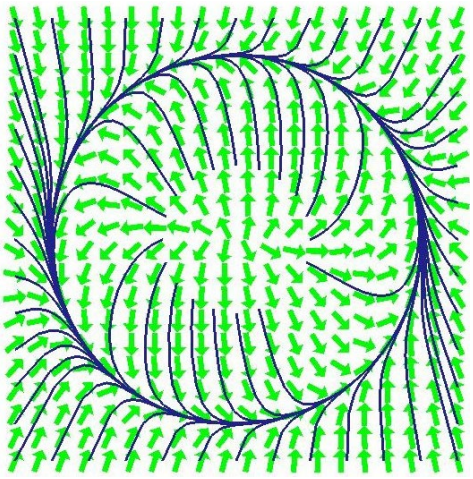

Fig. 3: Phase portrait *(u,v)* for example from Eq. (11)

Note that $(u,v) = (0,0)$ is a repelling fixed point. All transient solutions $(u(t),v(t))$, either from inside or from outside, rapidly converge towards the smooth solution following the unit circle. So this is a typical stiff situation. According to conventional folklore, the stiffness of an ODE system is characterized by the eigenvalue distribution of the Jacobian of its defining vector field. For the example from Eq. (11), these eigenvalues show such a typical behavior very close to the unit circle, but especially inside the unit circle, where transient solutions strongly increase, this is not the case and the eigenvalues are strictly positive, see [9].

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Centrality Measures in Flow Models of Complex Network Systems

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Abstract – This paper provides the analysis for functional approaches of complex network systems research. In order to study the behavior of these systems the flow adjacency matrices were introduced. The notions of measure, power, domain and diameter of betweenness of network nodes, edges, and separate subsystems are introduced to identify their significance in the operation process of network systems. These indicators quantitatively express the contribution of the corresponding components for the motion of flows in the system and determine the losses that are expected in the case of blocking this node or edge or targeted attack on it.

Keywords – complex network, network system, flow, centrality, betweenness, stability.

Introduction

To study any real network system (NS), whether natural or artificial, we have to form full and comprehensive representation of this system. Usually it is reached through observations, experimental and theoretical investigations and displaying the system as the models of different types [1]. When talking about network systems modeling, two main approaches may be distinguished: structural and functional. In modern NSs studies, the structural approach prevails, which is implemented in so-called theory of complex networks (TCN) [2]. The subject of TCN investigations is the creation of universal network structures models, determination of statistical features that characterize their behavior and forecasting networks behavior in case their structural properties change. Sometimes the term “complex network” (CN) is used to denote both structure and system [3], though these are fundamentally different concepts. The laws according to which the systems operate are usually much more complicated than the features of system structure, and methods of structural studies often do not allow us to solve NS functional problems [4]. Within the scope of functional approach, system structure is analyzed in conjunction with functions implemented by components of this structure and system in general, but the function takes precedence over structure.

The theory of binary networks is completely abstracted from the functional features of the NS. Weighted networks are an attempt to "tied" the functional characteristics of the system to the elements of structure [5]. Indeed, in each particular case, the weight of CNs edges is a reflection of certain functionality of the corresponding system [6]. Network, as a structure, is considered to be dynamic if the composition of its nodes and edges changes over time. The system is a dynamic formation, even if its structure remains unchanged. The system forms its structure in the process of development. The structure is being developed and improved from the needs of the system and not vice versa. What prompts the structure to develop, modify, or degrade? Movement of flows is one of the defining features of real NS. In some cases, providing the movement of flows is the main goal of creation and operation of such systems (transport and telecommunication systems, resource supply systems, trade and information networks, etc.), in others – the nesessary condition that provides their vital activity (blood and lymph flows, neuronal impulses in the human body). Stopping of flows movement leads to the termination of the NS existence.

This means the need to develop a conceptual apparatus and toolkit for studying the functional features of operation process of network systems components, beginning with their

elements and ending with the system as a whole. Introduction and research of functional analogues of well-known structural characteristics of complex networks elements is one of the ways to solve this problem. This allows us to compare the advantages and disadvantages of functional and structural approaches to the study of NS of different types and nature, to combine them in order to create a holistic view about the state and operation process of the system, and also contribute a deeper understanding of NS behavior and solution of some practically important problems [7].

Flow Adjacency Matrices of Network Systems

The network structure is completely determined by its adjacency matrix $\mathbf{A} = \{a_{ij}\}_{i,j=1}^{N}$, where N is the number of CN nodes. For the most studied binary networks, the value of a_{ij} is equal to 1, if there is a connection between the nodes n_i and n_j, and is equal to 0, if such connection is absent. Using the matrix **A** are defined the local and global characteristics of CN and studied its properties [3]. We describe the process of system functioning on the basis of flows motion analysis by the network and introduce the following adjacency matrices of NS:

1) the matrix of the density of flows which are moving by the network edges at the current moment of time t:

$$\boldsymbol{\rho}(t,x) = \{\rho_{ij}(t,x)\}_{i,j=1}^{N}, \quad x \in (n_i, n_j),$$

where (n_i, n_j) is the edge connected network nodes n_i and n_j, $i, j = \overline{1,N}$, $t > 0$;

2) the matrix of volumes of flows that are moving by the network edges at time t:

$$\mathbf{v}(t) = \{v_{ij}(t)\}_{i,j=1}^{N}, \quad v_{ij}(t) = \int\limits_{(n_i,n_j)} \rho_{ij}(t,x)dl, \quad t > 0;$$

3) the integral flow adjacency matrix of volumes of flows passed through the network edges for the period $[t-T,t]$ to the current moment t:

$$\mathbf{V}(t) = \{V_{ij}(t)\}_{i,j=1}^{N}, \quad V_{ij}(t) = \widetilde{V}_{ij}(t) / \max_{m,l=\overline{1,N}} \widetilde{V}_{ml}(t), \quad \widetilde{V}_{ij}(t) = \int\limits_{t-T}^{t} v_{ij}(\tau)d\tau, \quad t \geq T > 0;$$

4) the matrix of loading of network edges at time t:

$$\mathbf{u}(t) = \{u_{ij}(t)\}_{i,j=1}^{N}, \quad u_{ij}(t) = v_{ij}(t) / v_{ij}^{\max},$$

where $v_{ij}^{\max}$ is bandwidth of the edge connected the network nodes n_i and n_j, $i, j = \overline{1,N}$, $t > 0$;

5) the integral matrices of NS loading for period $[t-T,t]$ to the moment t:

$$\mathbf{U}^C(t) = \{U_{ij}^C(t)\}_{i,j=1}^{N}, \quad U_{ij}^C(t) = \max_{\tau \in [t-T,t]} u_{ij}(\tau),$$

and

$$\mathbf{U}^L(t) = \{U_{ij}^L(t)\}_{i,j=1}^{N}, \quad U_{ij}^L(t) = \Big(\int\limits_{t-T}^{t} u_{ij\,ij}^2(\tau)d\tau\Big)^{1/2} / T, \quad t \geq T > 0.$$

The introduced above flow adjacency matrices in aggregate give a sufficiently clear quantitative picture of the system's operation process, allow us to analyze the features and predict the behavior of this process, to evaluate its effectiveness and prevent existing or potential threats [8, 9]. The matrices $\boldsymbol{\rho}(t,x)$ and v(t) can be useful for the current analysis of network system's operation. The matrix V(t) enable to track the integral volumes of flows that pass through the

network edges. They are especially important in predicting and/or planning the NS operation and allow us to timely respond to deploying threatening processes in the system. The matrices u(t) and U(t) enable to analyze the current and integral activity or passivity of separate system components, as well as the level of their critical loading, which can lead to crashes in the NS operation. These matrices allow us to timely increase the bandwidth of network elements, build new ones or search the alternative paths of flows movement, etc. Many systems, e. g. transmission, processing and analysis of information are very dynamic formations [10]. Therefore, continuous monitoring of flows motion by the network is especially important in such systems [11, 12]. The introduced above flow adjacency matrices allow us to carry out such real-time monitoring.

Betweenness in Network Systems

One of the main concepts of TCN is the so-called centrality of the node, which allows us to determine its importance in the network: the most influential persons in social networks, key nodes on the Internet and transport networks, etc. [13]. However, the notion "importance" may have different content, which led to the emergence of many definitions of the term "centrality". The most used measures of centrality in a complex network include degree centrality, closeness centrality, betweenness centrality, eigenvector centrality, percolation centrality, cross-clique, Katz, and Page Rank centralities, harmonic, Freeman, and alpha centralities etc. At the same time, one measure of centrality may contradict another and the centrality that is important for one problem may be insignificant for another. This phenomenon was confirmed by D. Krackhardt [14], who gave an example of simple network, for which the degree, betweenness, and closeness centralities took completely different values, that is, gave three different choices of the most important nodes in system structure. Hence it follows that the mentioned above types of centralities have a quite relative value. This led to the introduction, along with the concepts of centrality the associated with them indicators of influence of nodes on the network structure. The main measures of the node's influence are its accessibility and expected force [15]. The accessibility of a node is determined by the number of nodes to which we can walk from it over a specified period of time. Expected force of a node's influence is determined by the number of nodes to which we can pass through two or more steps of motion (step – the transition by one edge of the network). Obviously, the above mentioned measures of centrality and influence of the node are determined solely by the properties of structure and are the characteristics of this structure, rather than system in general.

The influence parameters of system components were introduced in [7] and allow us to determine its importance in the system. These concepts enable to quantify the participation of separate node as a receiver or generator of flows in the process of system operation and its significance in this process. Another indicator of the importance of node interaction with NS is measure of its contribution in the transit of flows through the network. One of the most used with the degree centrality in TCN is the betweenness centrality. Perhaps the notion "betweenness " is most successful in determining the participation of NS's node in the process of joint operation and interaction of all nodes in the network or a certain part of it. Therefore, to determine the functional importance of a node or an edge in the system, we will use the term "betweenness ".

Denote by $P_{ij}^{K_{ij}} = \{p_{ij}^{k}\}_{k=1}^{K_{ij}}$ the set of paths that connect the nodes-generators and nodes-receivers of NS flows, and contain, as an element, the edge (n_i, n_j), $i, j = \overline{1, N}$. Let us $v_{ij}^{k}(t)$ is

the volume of flows that have passed through path p_{ij}^k from the node-generator to the node-receiver, and hence by the edge (n_i, n_j), for the period $[t-T, t]$. Then the value

$$V_{ij}^{K_{ij}}(t) = \sum_{k=1}^{K_{ij}} v_{ij}^k(t)$$

defines the total volume of flows that have passed through the set of paths $P_{ij}^{K_{ij}}$, and hence by the edge (n_i, n_j), over the same period of time. Parameter

$$\Phi_{ij}(t) = V_{ij}^{K_{ij}}(t) / s(\mathbf{V}(t)),$$

which determines the specific weight of flows passed through the edge (n_i, n_j) for period $[t-T, t]$, will be called the betweenness measure of this edge in the process of NS operation. The set L_{ij} of all NS's nodes, which lie on the paths of set $P_{ij}^{K_{ij}}$, will be called the betweenness domain, and the number η_{ij} of these nodes – the power of betweenness of the edge (n_i, n_j) (Fig. 1). Denote by δ_{ij} the diameter of betweenness domain of the edge (n_i, n_j). This diameter is calculated as the diameter of the set L_{ij}. Parameter $\Delta_{ij} = \delta_{ij} / D$ will be called the diameter of betweenness of the edge (n_i, n_j), $i, j = \overline{1, N}$.

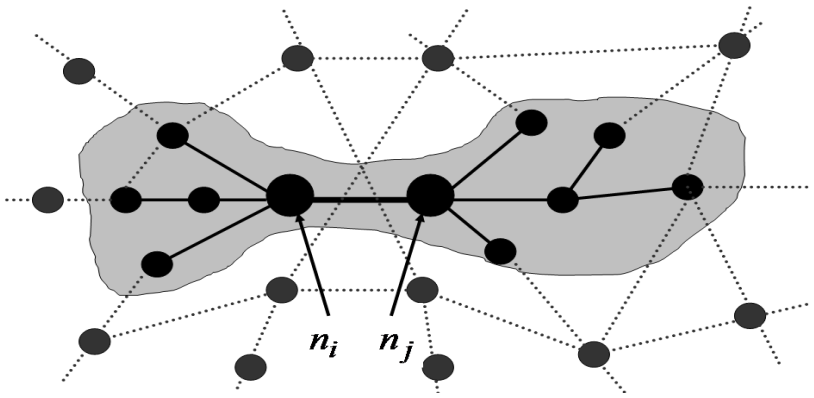

Fig. 1. The betweenness domain of edge (n_i, n_j) in the process of NS operation.

The parameters of measure, domain, power and diameter of betweenness of the edge (n_i, n_j) are global characteristics of its importance in the process of NS operation, $i, j = \overline{1, N}$. They, in particular, determine how the blocking of this edge will affect on the work of domain of its betweenness, the magnitude of this domain and, as a result, the whole system.

Denote by K_i the set of paths that connect nodes-generators and nodes-receivers of NS flows, and pass through a node n_i, $i = \overline{1, N}$. Let us $v_i^k(t)$ is the volume of flows passing through path p_i^k from the node-generator to node-receiver, and hence through the node n_i, for the period $[t-T, t]$. Then the parameter

$$V_i^{K_i}(t) = \sum_{k=1}^{K_i} v_i^k(t)$$

determines the total volume of flows that have gone through the set of paths $P_i^{K_i}$, and hence through node n_i, over the same period of time. Parameter

$$\Phi_i(t) = V_i^{K_i}(t) / s(\mathbf{V}(t)),$$

which determines the specific weight of flows passing through the node n_i for period $[t-T,t]$, will be called the betweenness measure of this node during the NS operation. The set M_i of all NS's nodes, which lie on the paths of set $P_i^{K_i}$, will be called the betweenness domain, and the number η_i of these nodes – the power of betweenness of the node n_i. Denote by δ_i the diameter of betweenness domain of the node n_i. Then parameter $\Delta_i = \delta_i / D$ will be called the diameter of betweenness of the node n_i, $i = \overline{1,N}$.

The parameters of measure, domain, power and diameter of betweenness of the node n_i, $i = \overline{1,N}$, are global characteristics of its importance in the process of NS operation. They, in particular, determine how the blocking of this node will affect on the work of domain of its betweenness, the magnitude of this domain and, as a result, the whole system.

Betweenness parameters allow us to define the following scenarios of attacks on the network system:

1) a list of network nodes is being prepared in order of decreasing the values of their betweenness measure and the nodes from the beginning of this list are consistently withdrawn from the structure until a predetermined level of critical losses is reached;

2) after removing the next node, the list of nodes formed in the previous scenario is rewritten according to the same principle and the attack is carried out on the first node from the modified list.

The second scenario takes into account the need to replace blocked nodes-generators and nodes-receivers of flows and the search for alternative paths of movement of transit flows that pass through blocked nodes, i.e. the corresponding redistribution of flows motion through the network. Similar scenarios of attacks are also formed for NS's edges, since in many cases the blocking of network edge is much simpler than blocking one of the nodes that it combines. The parameters of betweenness of nodes and edges allow us to estimate to what part of the NS the consequences of failures of the corresponding system element will spread and to what losses this will result in the sense of lack of supply of certain volumes of transit flows.

Betweenness of Subsystems of Complex Network Systems

Denote by S the subsystem of source NS, formed on the basis of principles of ordering or subordination [16]. Let us H_S is the set of nodes that make up the structure of subsystem S, and F_S is the set of edges that combine nodes of the set H_S. Equally important for the analysis of NS operation are the parameters of betweenness of its separate subsystems, which we define as follows. Denote by $P_S^{K_S} = \{p_S^k\}_{k=1}^{K_S}$ the set of paths that combine the NS's nodes-generators and nodes-receivers of flows and pass through elements of the subsystem S. Let us $v_S^k(t)$ is the volume of flows that went through path p_S^k from the node-generator to node-receiver, and hence through the elements of subsystem S, for the period $[t-T,t]$. Then parameter

$$V_S^{K_S}(t) = \sum_{k=1}^{K_S} v_S^k(t)$$

determines the total volume of flows that went through a set of paths $P_S^{K_S}$, and therefore through elements of the subsystem S, over the same period of time. Parameter

$$\Psi_S = V_S^{K_i}(t) / s(\mathbf{V}(t)),$$

which determines the specific weight of flows passing through elements of subsystem S for period $[t-T,t]$, will be called the betweenness measure of this subsystem during the NS operation. The set M_S of all NS's nodes, which lie on the paths of set $P_S^{K_S}$, will be called the betweenness domain (Fig. 2), and the number η_S of these nodes – the power of betweenness of subsystem S. Denote by δ_i the diameter of betweenness domain of the node $n_i \in H_S$. Then parameter $\Delta_S = \max_{n_i \in H_S} \delta_i / D$, will be called the diameter of betweenness of subsystem S.

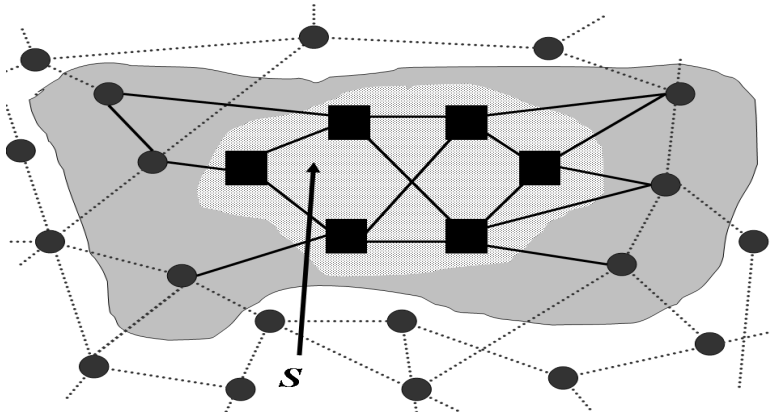

Fig. 2. Betweenness domain of subsystem S in the process of NS operation.

The parameters of measure, domain, power and diameter of betweenness of subsystem S are global characteristics of its importance in the process of NS operation. They, in particular, determine how the blocking of this subsystem will affect on the work of domain of its betweenness, the magnitude of this domain and, as a result, the whole system. In addition, the small values of betweenness parameters of the subsystem S may also indicate that it forms a community within the NS.

Conclusions

The functional approach of network systems research is considered in this article. In order th study the process of such systems operation the flow adjacency matrices of different types were introduced. It was also analyzed, how these matrices help to investigate and forecast the peculiarities of this process, evaluate its efficiency and prevent existing and potential threats. Global dynamic betweenness parameters of the network systems elements were determined. These parameters allow us to form much more realistic scenarios of potential attacks on the system, quantify the losses from these attacks, and build the more reliable means of protecting it. The parameters of betweenness of network system components defined in the article enable to identify the most important subsystems for NSs operation and contribute to a better understanding of the processes that occur in them. Obtained results can be used to reduce the NS vulnerability from negative external and internal influences, to develop the modern methods for

information and security systems protecting, to improve the efficiency of operation of transport and industrial networks of different types, etc.

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Modeling figure and orientation of the Earth's lithosphere based on paleoDEM

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Abstract – The purpose of the research is to determine the displacement of points of the Earth's surface in geological time based on the results of geopaleoreconstructions using the digital elevation model (paleoDEM). By approximating paleoDEM to the form of simple geometric shapes (biaxial and triaxial ellipsoids). their parameters are obtained, and the orientation relative to the ellipsoid that describes the geoid.

Keywords – biaxial ellipsoid, triaxial ellipsoid, paleoDEM, lithosphere.

Introduction

The purpose of the research is to determine the displacement of points of the Earth's surface in geological time based on the results of geopaleoreconstructions using the digital elevation model (paleoDEM) [2]. It is clear that it is best to estimate the global displacements of the lithospheric surface, generalizing it in the form of simple geometric shapes (biaxial and triaxial ellipsoids)[4]. Topological non homothetic of placing a figure of a lithosphere and a geoid figure can create tectonic stresses. They are aimed at bringing the distribution of the masses of the lithosphere in accordance with the figure of the geoid (according to the mechanism of gravitational forces and the principle of minimizing potential energy), and due to the discharge of stresses, there is a mechanism of approaching the polar axis of the generalizing lithosphere to the axis of rotation (the polar axis of inertia). In addition, the field of rotational stresses caused by the displacement of the axis of the generalizing lithosphere figure obviously will tend to movements in the Earth's lithosphere synchronously with the movement of the axis of the figure in the process of its evolution. In this regard, the article also considers one of the reasons of possible causes of the lithospheric stress associated with the change in the Earth's shape in the process of evolution, i.e. it is assumed that the generation of the field of stress is conditioned by the transformation of the topological surface from one ellipsoid to another. In this sense, the modelling of the stress state of the Earth's lithosphere may possibly allow us to come closer to the correct understanding of the influential factors and the role of driving forces in the concept of plates tectonics.

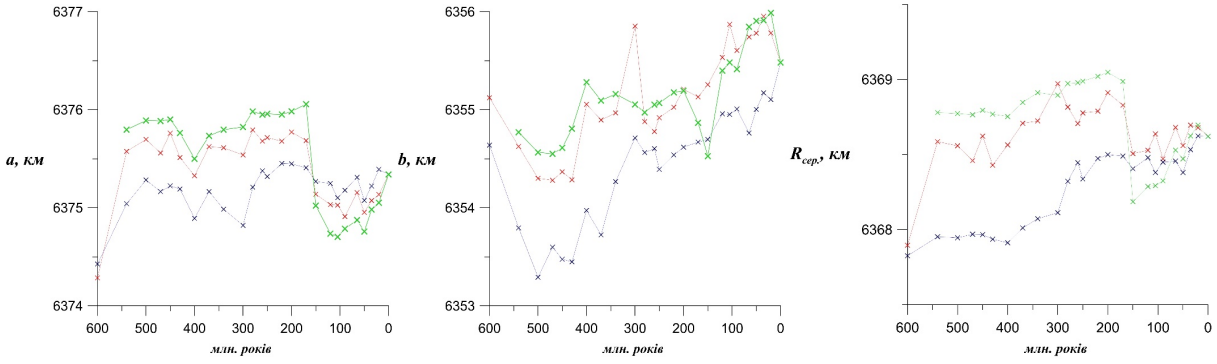
The results obtained and discussion

According to the results of previous studies, it was found that the surface of the lithosphere is geometrically rotated relative to the figure of the geoid and in the geological time changed the orientation of these figures and the parameters of the approximating ellipsoids [4]. For the modern era, the value of the turning angle between the smallest axis of the ellipsoid, which approximates the surface of the lithosphere, and the axis of Earth’s rotation is 2,6° [6]. An interesting task is to track the change of this turning angle in the process of evolutionary self-development of the planet, as this factor accumulates a complex of dynamic mechanisms of the emergence and formation of the main elements of tectonic structures through endogenous processes and the rotary motion of the Earth. As a result of the gravitational-rotational and endogenous forces, a redistribution of masses occurs, which can lead to the transformation of the figure from the twoaxial ellipsoid to the triaxial and vice versa, changes in compression and the axial velocity of rotation and the displacement of the pole in geological epoch.

To date, the most significant studies in the sense of geopaleo-constructions are performed by Christopher R. Scotese and N. Wright [2]. They have built a paleo digital elevation model (paleoDEM) - a digital representation of palaeotopography and paleobathymetry, which was "reconstructed" in time. PaleoDEM accumulates the creation of 120 palaeogeographical reconstructions, which are part of the palaeographic atlas PALEOMAP. The basis for the construction of the paleographic atlas was laid 177 fragments of the paleo reconstructions of the Phanerozoic and 3 fragments of the Precambrian paleo reconstructions. Each PaleoDEM is an estimate of the heights of the surface of the land and the ocean basin's depths, defined in meters with a resolution of $1° \times 1°$.

According to the approximation of biaxial and triaxial ellipsoids of the heights of the Earth's physical surface, results were obtained that characterize their parameters in the modern period (see tabl. 1 and 2), and for various past geological epochs, according to the data obtained by K. Scotese and N. Wright [2]. In the article [5] similar studies of geoevolutionary changes in the figure of the Earth were carried out on the basis of two variants of raster maps of the paleoreconstruction of the continents placement and the water surface, which were independently created by R. Blakey [1] and K. Scothese [3]. Since all raster images were created consistently in certain colors, by finding a connection between the image of the altitudes of the model ETOPO1 and bitmap maps of the paleoreconstruction, with a certain approach, a transition to the digital surface topography model (DSM) of the Earth's lithosphere for geological epochs that were tied to corresponding maps showing the continents and the water surface. It would be advisable to show the relation between the results of previous studies and the results of approximation by biaxial and triaxial ellipsoids of the heights of the paleo-digital model of relief (paleoDEM).

Fig. 1 shows the graphs of the change of the minor and major semi-axes of the biaxial ellipsoid, as well as the mean radius during of geological time. The blue color shows a curve that corresponds to the approximation of the modeled values for raster paleoreconstruction R. Blakey. Red curve according to the modeled values of K. Scotese. Green shows the results obtained by the input data, which are covered in this paper. As we see, changes in all quantities reflect such tendencies in geological time, although some differences are present. Such a division demonstrates the reliability of the results obtained, since different inputs data were used.



a) b) c)

Fig.1 Changes in the parameters of a biaxial ellipsoid a) - a major semi-axis, b) - a minor semi-axis, c) - an average radius during geological time

Interesting for understanding is fig. 2, which shows the positions of the pole of the minor axis of the figure of a biaxial ellipsoid, depending on latitude. As we see here, there is no relative displacement, obviously, because the angular values, unlike the sizes of axes and compression, are independent of the scale of the ellipsoid's models. We also note that in the position of the

pole there are clearly two major deviations from the axis of rotation. This is in the modern period and nearly 400 Ma. In the time interval of 100-300 Ma, the deflection of the pole was within 1 °. Proceeding from the figure, the results according to K. Skotese and R. Blakey are well coordinated. Consequently, the significant movement of the pole of the figure, if given to it semantic geological meaning, may indicate the activation of tectonic processes in these periods of geological time.

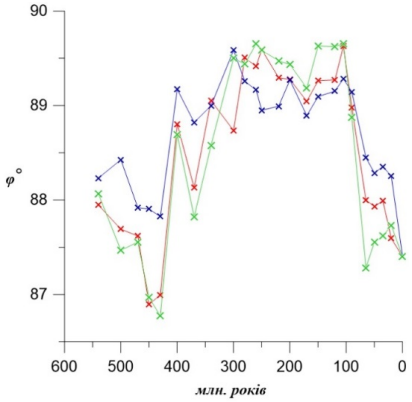


Fig.2 Deviation of the pole of a biaxial ellipsoid during geological time

Note, that in the results obtained from the approximation of the heights of the paleo-relief, there are clear regularity in the compression of two ellipsoids (biaxial and triaxial), which are shown in fig. 3. An orange color reflects the compression of the figure of a biaxial ellipsoid, while black is a compression of the triaxial ellipsoid in the meridian plane (0°-180°):

$$\alpha = \frac{a_x - a_z}{a_x} \qquad (1)$$

Yellow – in in the meridian plane (90°-270°):

$$\alpha = \frac{a_y - a_z}{a_y} \qquad (2)$$

Purple – polar compression:

$$\alpha = \frac{\sqrt{a_x a_y} - a_z}{\sqrt{a_x a_y}} \qquad (3)$$

Also, in this graph, two periods in the history of the Earth (470 Ma and 160 Ma) can be traced (according to the biaxial ellipsoid), during which the compression was maximal, we note that the third period with the greatest compression of the planet takes place at the present time. The difference between the ellipsoid semi-axes is about 20 km.

The opposite trend is observed in the period of 65 Ma, then the planet had less compression, and the difference between the semi-axes was about 17 km. The difference in the compressions of ellipsoids in size of 3 km transformed the area of the figure which is the most significant in the polar zones has caused tectonic activation.

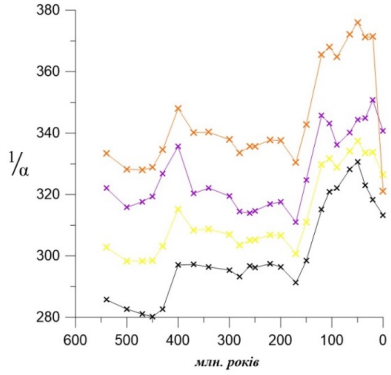


Fig.3 Changes in compression of a biaxial and triaxial ellipsoids during geological time

Interesting are the graphs for changing the difference between the major and minor axes of a triaxial ellipsoid in the plane of the equator, which are shown in Fig. 4. They show a clear transformation of the two-dimensional ellipsoid into a trivial one, which occurred 400 million years later. In that period of the geological time, the continental and oceanic surfaces of the lithosphere were best described by a triaxial ellipsoid with a difference in axes in the equatorial plane of ~ 3.2 km, and 50 million years later, a similar indicator reached only 0.5 km. At the present time, this indicator is 1.5 km.

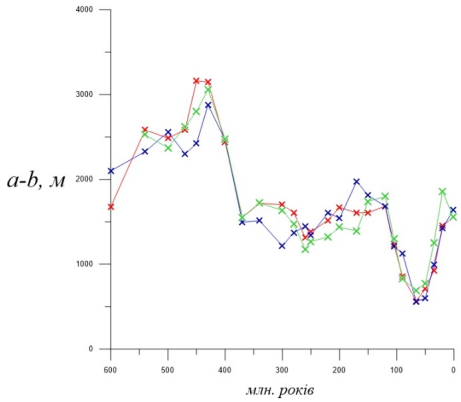


Fig.4 The graphs of the difference between the major and minor axes of the triaxial ellipsoid in the plane of the equator by the results of the modelling

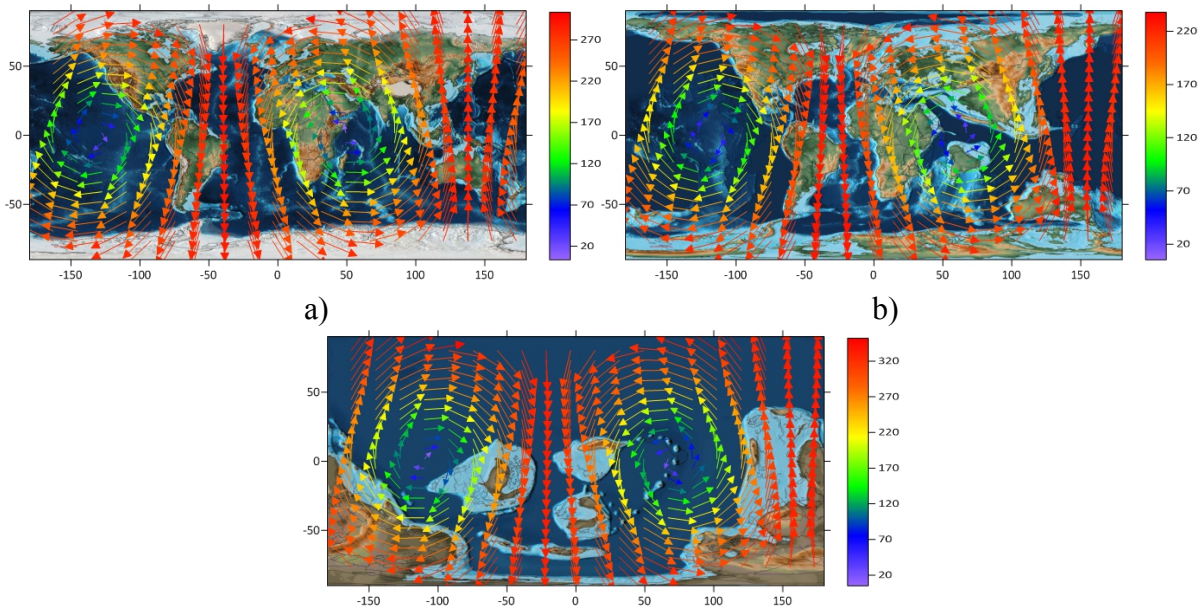


Fig.5 Moving the points on the surface of the ellipsoid (km): a) - the modern era, b) - 65 Ma, c) - 470 Ma

The general system of displacements is a system with two vortices whose focuses are located in the region of equator, and the landslide deformation parameters in them are minimum about 20 km (fig. 5). As deviations from these epicentres deformation parameters increase. From the figure we see that the "main" lines of deformation are located along the meridians, with these strips at a width of about 50 degrees in length. Their maximum value is about 320 km in the period of 470 Ma. Also, maximum displacement is observed in the polar regions. Directions of displacement are opposite in these vortices, and are absolutely symmetric. As the parameters of the reorientation of the figures change, the epicenter moves somewhat. It is logical that this should cause a constant change in the stresses in the cortex and, accordingly, a change in the tense state of the lithospheric shell. Therefore, there must be a moment of critical stresses that

provoke irreversible deformation processes that give rise to linear structures and faults.

Conclusion

Due to such deviations of the two main Earth's figures which approximates surface of lithosphere and geoid, individual blocks of the crust are in a permanent state of motion, and accordingly will change the field of deformations and stresses. In our opinion, this is one of the possible factors of the process, which provokes global movements of lithospheric blocks. As a result, there is a transformation of the lithosphere, which is characterize by a change in the size of the ellipsoid axes, which describes the surface of the lithosphere, and their orientation. In this case, the Earth can be consider as a dynamic system, in which there is a regular change in volume, with the general tendency to increase it. The mass of the Earth remains constant, and the Earth itself cyclically expands. On the other hand, the implementation of the principle of minimizing gravitational energy, providing that the mass and moment of inertia of the planet remain constant, converts a homogeneous Earth into a multilayer.

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A Method for Determining of the Maximum Possible Pixel Format of Object Image Memorizing during its Photography

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Abstract — the method of rational choice of the maximum possible pixel format of image memorization in photo equipment is proposed and substantiated. It allows you to limit the file size to an electronic image without losing the specified level of object recognition by its image. The method is based on the filtering properties of the lens and photosensitive matrix of photoequipment, which are estimated by the methods of spatial-frequency analysis.

Keywords – object photography, image, recognition probability, modulation transfer function, thresholds contrast, photosensitive matrix, pixel size.

Introduction

Photoequipment is one of the main technical means for obtaining of an object image. Active directions of its application are photogrammetry, geodesy, mapping and many others. Its widespread use meets such requirements as ease of use, accessibility, compactness, autonomy, documentary, accuracy of reproduction in the image of the appearance of an object, etc. In the special literature, user's manuals for specific camera samples, a wide range of their parameters and characteristics are given which are responsible for such a functional convenience of the photoequipment [1]. It is believed, that for the accuracy of the reproduction of the object appearance in the image, i.e. for image quality the two parameters correspond to this: the pixel size of the photosensitive matrix and the level of compression of the electronic image [2].

Both parameters are limited by their maximum and minimum values for each of the specific camera samples. Between the maximum and minimum values of parameters also provides for operator the ability to select a series of intermediate values [3]. For the matrix pixel size according to the offers of the photoequipment manufacturer companies, such values is up to ten, for the level of compression, usually, such gradations are two – normal quality and high quality.

In addition to the image quality, both parameters form another property of the image – its byte size. At that, with the increase in the values of both parameters, an increase in image quality is expected. Therefore, the maximum possible pixel size of the photosensitive matrix is considered better than it is more [4]. As a result, even in devices adapted for photography (smartphones, tablets, photo-toys), cameras such as "pocket" already as usual the maximum possible pixel sizes in 18, 12, 10 ... megapixels (Mp) [4]. With such set pixel formats digital image memorizing, it's even compressed in JPEG format electronic images will be several megabytes.

The question arises – is it always advisable to work with electronic images of this size? If the input signal is an optical image, constructed by a photocamera lens, has resolution, which is, at least, the same as the possibility of its discretization by a photosensitive matrix, and switching processing scheme can operate with the necessary frequencies, it makes sense. That is, the image quality level of the photoequipment must be guaranteed by sufficient throughput of the three components: an objective, a photosensitive matrix, switching-processing schemes.

The pixel size of semi-format photosensitive matrices for cameras has reached values of tens of megapixels, that corresponds to the diffraction limit of the single elementary receiver size (pixel). For electronic schemes, the picosecond intervals of action are already mastered [5]. Let us look at the optical image.

The source of the primary optical image is the camera lens. Right here the boundary quality of an electronic image is formed, which can be obtained by given sample of photoequipment. In the article, one of the methods of rationalizing the choice of photoequipment is considered for making photography of an object without loss of quality indicators of an image or the choice of rational intermediate value of pixel size of photosensitive matrix (rational pixel size of electronic image) during photography of the object.

We will base on two assumptions. Firstly. Within the same image, simultaneously there are images of several objects. We believe, that during of photography obtaining a qualitative image of the smallest object (object j with the smallest linear size of the distinguishing sign $l_{\text{recogn,j}} = l_{\min}$ will guarantee a high-quality image of the remaining objects in the frame [6].

Secondly, the image quality will evaluate by the probability of object recognition by its image. Then we can say that the probability P of object's image recognition depends on the distance of photography S and the parameters of the photoequipment [7]:

$$P = \exp\left[-\frac{\ln P_{\text{given}}}{\lg \frac{1-K}{1+K}} \left(\frac{dS}{fl_{\text{recogn.}}} \right)^2 \right], \qquad (1)$$

where: K - contrast of the subject of photography (it is the constant for this object in the given conditions of photography); d - the linear size of the element of differentiation of the photoequipment; f - focal length of the lens of the photoequipment.

The purpose of the photography will be achieved if the probability of the object's image recognition P will exceed a certain value of P_{given} - the given probability of recognition. In practice, it is important to determine the maximum possible photography distance, within which the results of photography will solve. At the same time, the choice of the photography point is as diverse as possible. For the maximum distance of the photography point from the object value $P = P_{\text{given}}$, and the distance within which it is possible to choose the photography points of the object, provided that the task is fulfilled in a photograph with a given probability of P_{given}, will be the maximum possible $S_{\max}$.

Thus, in this case formalized description of photography reflects hardware capabilities influence on its result provided the maximum distance and given quality of the object's image:

$$\text{I.} \quad \begin{aligned} & P_{\text{given}} = P; \\ & \frac{S_j d}{f} = \text{const}; \\ & S_j = \text{const} \cdot \frac{f}{d} = \max; \\ & L_j = \min, \quad j = \overline{1,J}. \end{aligned} \qquad (2)$$

The photography distance S=max will be maximal for f/d_{camera} = max. As a result, the maximum possible photography distance can be increased by increasing of the lens focal length or by reducing of the linear size of the resolution element in the image.

Enlarging of the lens focal length f of the photoequipment (enlarging of the image scale) and, accordingly, selecting of the photoequipment with increased zoom, will enable successfully to make an object photography for diverse scale. However, we need to remember, that working with such long-focal photoequipment may to arise such operational difficulties:

- an angle of the field of view of the photoequipment lens decreases significantly;

- increasing of the shutter speed during photography, that leads to fuzzy image;
- the focusing process becomes complicated due to possible obstacles between the photoequipment and the object.

Reducing the linear size of the resolution element d will give the possibility to avoid disadvantages mentioned above and. It can be realized by selecting photoequipment with a maximum pixel size. In this case, we have to consider such contradiction.

In Eq. (2) d is the linear size of the resolution element of the photoequipment during photography. The main factors that influence to its value are the spatial properties of the lens and receiver - a photosensitive matrix. The mechanical increase of the pixel size of the photosensitive matrix will, certainly, contribute to the fulfilling the task, but only until the limitation of the lens spatial properties will not interfere for this.

Further increasing of the photosensitive matrix pixel size will lead only to increase the images files size, which makes difficult to work with them. We will need information storage devices of greater capacity, time to remember is increasing, limitations on image transmit by electronic paths are arising. If this is accompanied by an improvement in image quality, this approach is justified. If there is no image quality improvement, the increase in the pixel size of the matrix is unnecessary and irrational.

The universal border of the rational photosensitive matrix pixel size is absent. The better the photoequipment lens, so this limit is more. Therefore, at the article proposed an algorithmic method for its determination, verified by a natural experiment.

Statement of the problem and basic equations

To compare the iconic properties of photoequipment samples or its components, it is accepted to apply a spatial-frequency analysis [8-12] with an experimental verification of the obtained data (the adequacy of the mathematical modeling of the object of research should be proved by the results of the semi-natural modeling).

The basic for the analysis is the notion of the modulation transfer function (MTF) of a photoequipment $T(\nu)$ [8]:

$$T(\nu) = T_{\text{lens}}(\nu) \cdot T_{\text{receiv}}(\nu) = T_{\text{diff}}(\nu) \cdot T_{\text{aberr}}(\nu) \cdot T_{\text{receiv}}(\nu), \qquad (3)$$

where $T_{\text{lens}}(\nu)$ - MTF lens; $T_{\text{receiv}}(\nu)$ - MTF of the matrix receiver; $T_{\text{diff}}(\nu)$ - MTF, limited by diffraction (diffraction limit); $T_{\text{aberr}}.(\nu)$ - MTF, limited by scattering (aberration component); ν is the spatial frequency.

In [9], the MTF $T_{\text{diff}}(\nu)$ of the non-collateral lens (the diffraction limit) is defined by the following equation:

$$\grave{O}_{\text{diff}}(\nu) \approx 1 - k_D \nu / 1400, \qquad (4)$$

where k_D is the diaphragm number.

Taking into account the spot of the aberration scattering σ_f in case of defocusing by the value Δf it is possible to write [10]:

$$\grave{O}_{\text{diff}}(\nu) \approx \text{Sinc}(\pi \sigma_f \nu) = \text{Sinc}\left(\pi \frac{\Delta f}{k_D} \nu \right), \qquad (5)$$

where σ_f is the diameter of the spot of the lens aberration scattering. For photographic lenses $\Delta f \approx (0{,}01 \ldots 0{,}001) f$.

The MTF of the matrix receiver $T_{\text{receiv}}(\nu)$ is determined by the geometric size of the

elementary receiver – the pixel [11, 12]:

$$T_{\text{receiv}}(\nu) = \text{Sinc}^2(\pi d\nu), \qquad (6)$$

where d is the linear pixel size.

Eqs. (3) - (6) is a mathematical model of the photoequipment MTF. To involve to the analysis the photoequipment resolution, we must also be determined by the signal-noise ratio, which restricts the human's ability to perceive small low contrast parts of the image. The analogue of the dependence of the signal-to-noise ratio from the input signal in a photograph is called the boundary contrast curve. Exactly the common point of the MTF of the photoequipment $T(\nu)$ and boundary contrast curve $K(\nu)$ determines the boundary space frequency ν_{max}, on which the object's image details yet may be differ by the human eye [8]. In this case, the following equation is solved:

$$T_{\text{receiv}}(\nu_{\max}) = \hat{E}(\nu_{\max}) \qquad (7)$$

Eq. (7) are solved analytically or graphically. Because the image of the object is considered on the screen, on the monitor, on the photoprint at a increase that does not detect its raster (per pixel division), the threshold contrast in this case can be considered independent of the spatial frequency and determine by the contrast sensitivity of the human eye K_{eye}.

In this case, the Eq. (7) will have this form:

$$T_{\text{receiv}}(\nu_{\max}) = \hat{E}_0. \quad (8)$$

The intersection point of the MTF of the camera with the level of contrast sensitivity K_{eye} of the human eye will correspond to the spatial frequency, on which yet will perceive the details of the image of the recognizable feature of the object.

Results and discussion

When evaluating and comparing the spatial-frequency properties of various samples of photoequipment, the following should be taken into account. Camera lenses usually have different focal lengths, which changes within the range of optical zoom (zoom of photoequipment lens). Therefore, when comparing MTF of the separate sample of photoequipment with different zoom values, and comparing MTF of the different samples of photoequipment at their joint consideration, it is necessary to take into account the scaling factor k_{scale}:

$$k_{\text{scale,1-2}} = \frac{f_1}{f_2}, \qquad (9)$$

where f_1 is the focal length lens of the first sample (the first value of the lens zoom of the photoequipment); f_2 is the focal length lens of the second sample (the second value of the lens zoom of the photoequipment).

The spatial frequencies for lenses with different focal lengths (with different zoom values) thus will be connected by the following equation:

$$\nu_2 = k_{\text{scale}}\nu_1 = \nu_1 \frac{f_1}{f_2}. \qquad (10)$$

The algorithm Eqs. (3)-(9) gives possibility on one spatial scale to build a MTF family for each sample of photoequipment within its zoom, and also to compare the families of such curves

with each other. This will allow determining the most rational samples that are put into the general scheme of evaluation of MTF to compare the efficiency of the use of iconic means [13]. Initial data for comparison:

- MTF photoequipment is calculated according to the algorithm (Eqs. 3-6, 9);
- aberration defocusing is determined by the condition $\Delta f = 0{,}01f$ [9];
- the linear pixel size d is calculated for the known diagonal of the photosensitive matrix c (c = 10.9 mm),
- the pixel sizes of the photosensitive matrix ($N_A \times N_B$) ($N_A \times N_B$ = 4320×3240, …, 640×480) for memorizing format 4:3,
- the linear sizes of the photosensitive matrix A and B according to the equations:

$$d = \frac{A}{N_A}; A = \frac{4}{5}c. \quad (11)$$

Comparison of MTF is carried out in two stages. At first, we will determine with the influence of pixel format storage on image quality. Then we will evaluate such influence for the minimum and maximum focal length, the area between them - the space of the existence of MTF of given sample of camera. In the calculations of the scaling coefficients, k_{scale} for different values of the lens zoom for the base choose spatial frequency for the minimum focal length.

Let's analyze the influence of pixel memorizing format $N_A \times N_B$ of the Panasonic TZ18 Lumix camera [14] (Leika Vario-elmar ASP H lens, 4.3-68.8 mm, 16×) on image quality. To do this, we calculate the MTF of the light-sensitive matrix $T_{receiv}(\nu)=T3(\nu)$, the photoequipment MTF $T(\nu) = T4(\nu)$ for all memorizing formats $N_A \times N_B$ ($N_A \times N_B$ = 4320×3240: 14 Mp; 3648×2736: 10 Mp; 3072×2304: 7 Mp; 2560×1920: 5 Mp; 2048×1530: 3 Mp; 640×480: 0.3 Mp). The selected camera is a typical sample of brand-name quality camera manufacturing in the class "pocket".

The results of calculations by the algorithm Eqs. (3) - (7), (9, 10) are shown in Fig. 1, where, in addition to MTF, the boundary contrast $K(\nu) = K_0$ of the human eye at the level of 0.02 is shown [13].

Analysis of graphic dependencies on Fig. 1 allows us to make the following conclusions. Transmitting properties of the photosensitive matrix will affect to the appearance of the MTF of the Panasonic TZ18 Lumix camera to a large extent with a memorization format of 0.3 Mp. Significantly, less this effect will be observed in the memorizing format of 3 Mp, and almost invisible it becomes after the memorizing format at 7 Mp. This applies both to the boundary spatial frequencies (about 60 ... 70 mm^{-1}), and to the contrast of the image at medium spatial frequencies (20 ... 50 mm^{-1}).

That is, the filtering properties in the photosensitive matrix are only up to its pixel size of 7 Mp. The camera lens becomes a cut-off, a filtering element for bigger spatial frequencies in an optical image. A further increase of memorizing format will not change the image quality, although its bytes size will increase by quadratic dependence.

Natural modeling (Fig. 2) confirms the effectiveness of the developed algorithm. As objects of photography used 72-beam radial measure. The image quality was evaluated by the definition of the displaying scattering circle diameter on the measure.

In the case of an increase of the focal length, the maximum spatial frequency increases proportionally, within which the image is constructed. Simultaneous increase (per order) of the pixel size of the photosensitive matrix affects to the image quality insignificantly. We can also affirm, that in this case the determining factor of the MTF of a camera $T4(\nu)$ is MTF of

aberrational defocusing, and the existence of saving image pixel format in 14 Mp is a marketing move.

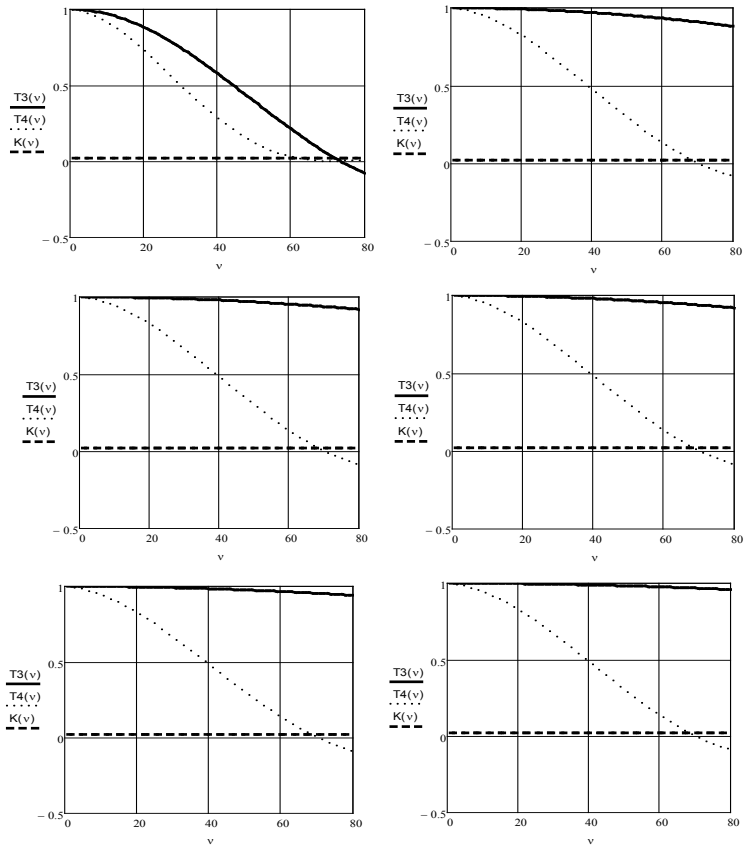
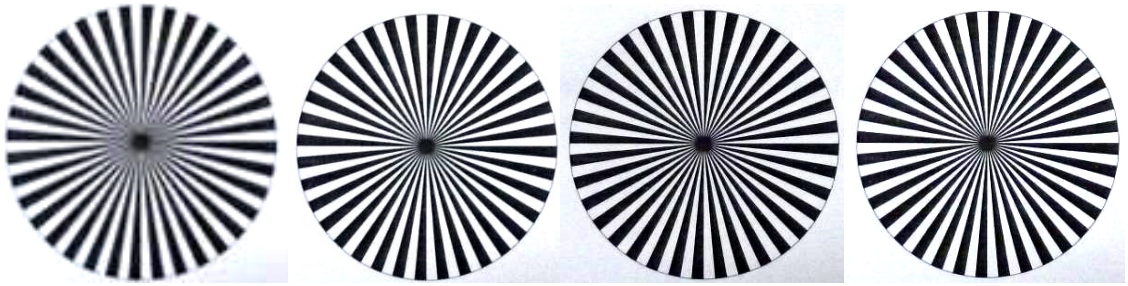


Fig. 1. MTF Panasonic TZ18 Lumix T4 (ν), boundary contrast K (ν) and MTF of the light-sensitive matrix $T3$ (ν) for memorizing formats:
a – 0.3 Mp; b – 3 Mp; c – 5 Mp; d – 7 Mp; e – 10 Mp; f – 14 Mp

The calculated and experimental results obtained indicate that increasing the pixel size of photosensitive matrices beyond the limits of their effect on image quality is inefficient (Figs. 3 and 4). The boundary of influence is determined by the level of aberration of the write-off of each particular lens of the photoequipment, that is, the quality of manufacturing of the lens optics and its input diameter (the maximum of the diaphragm number).



a *b* *c* *d*

Fig. 2. Panasonic TZ18 Lumix camera images of a test object in memory formats: a – 0.3 Mp;
b – 3 Mp; c – 7 Mp; d – 14 Mp

The obtained results can be extended, first of all, to all samples of photoequipment with a small diameter of the lens, that is, cameras such as "pocket", smartphones, and other devices adapted for photography. For a more or less precise definition of the limit to rationally increase the pixel size of image memorization (or increase the pixel size of the photosensitive matrix), it

is necessary to know the actual values of the MTF of a particular lens.

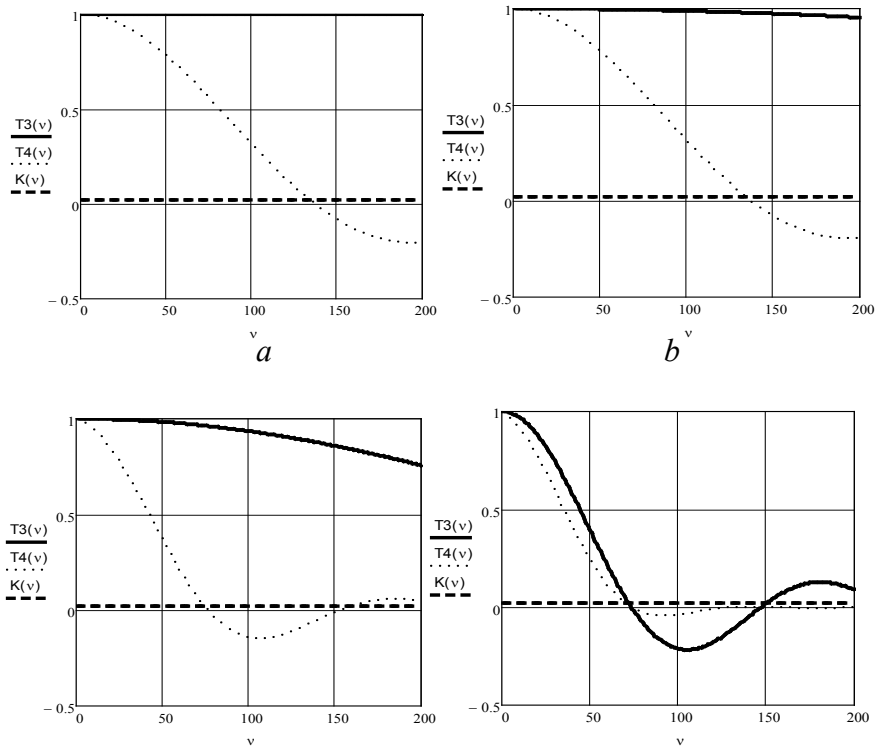


Fig. 3. MTF *T*4 (ν) of the Panasonic TZ18 Lumix camera, boundary contrast *K*(ν) and MTF *T*3(ν) of the photosensitive matrix: *a* – *f* = 68.8 mm, 0.3 Mp; *b* – *f* = 68.8 mm, 14 Mp; *c* – *f* = 4.3 mm, 0.3 Mp; *d*– *f* = 4.3 mm, 14 Mp

Some corporations (Sony, Nikon, Leika) point out on their sites such data for most of the photoequipment (photo lenses). The universal method for obtaining information on lens MTF is its experimental measurement [15, 16] for each photoequipment type (the corresponding measuring equipment is available in the subdivisions of all leading manufacturers of photoequipment).

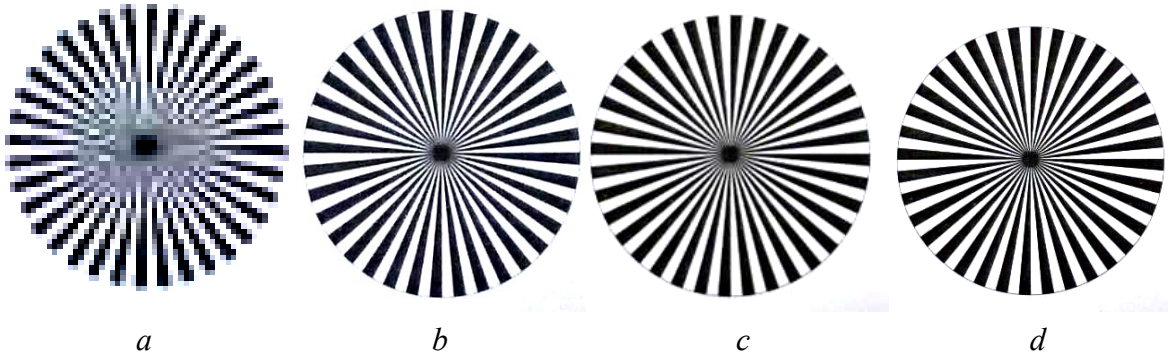


Fig. 4. Panasonic TZ18 Lumix camera pictures of a test-object for memory formats: *a* – *f* = 4.3 mm, 0,3 Mp; *b* – *f* = 4.3 mm, 14 Mp; *c* – *f* = 68.8 mm, 0.3 Mp; *d* – *f* = 68.8 mm 14 Mp

In the presence of MTF measurement data, it is possible to predict the expediency using of enlarged pixel image memorizing format in specific photoequipment sample. Such forecasting will allow to reduce the cost of information - for communication, processing, storage, as well as financial - for the purchase of photoequipment (with increasing pixel size photosensitive matrix increases the cost of photoequipment) to take a photography of the object.

Conclusions

We can to affirm, that an enlargement of the pixel size of a photosensitive matrix leads to an improvement of the image quality only in the case of a matching improvement in the photoequipment lens quality by reducing its aberration defocusing. Forecasting of the photoequipment image properties will allow increasing object photography efficiency. In further it will be useful to determine the most adequate criterion for evaluating the image properties of photoequipment by its MTF and take into account operational factors in forecasting algorithms account.

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Calligraphy as an art in islamic architecture and its significance today

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Abstract – Art moves human beings and satisfies their emotional dimensions. Artistic emotional response inspires a man to shed light on the wisdom of human existence as well as facial appearance of the universe. Every religion, after spreading spread with them their culture, values, principles etc. in the form of art and architecture. In the Islamic world, calligraphy has been used to a much greater extent and in astonishingly varied and imaginative ways, which have taken it far beyond pen and paper into all art forms and materials. The aim of this paper is to understand the use of Arabic calligraphy in Islamic buildings in past taking examples of monuments in New Delhi, India and comparing them with the modern buildings. This will help in forming strategies and techniques to implement the calligraphic art in architecture today.

Keywords – Calligraphy, Islamic Art and Architecture, Quranic verses, Modern buildings.

Introduction

Art has always helped human beings to cherish uncertainty, intuition & creativity and to search constantly for new ideas. Art helps human beings to identify with one another and expand the notion of being global from local. Artistic emotional response inspires a man to shed life on the depth of human existence and facial emergence of universe. Thinkers and artists of all times agree with the fact that, "art, a creative course of action is the expression of frame of mind, feeling and spirit." The space-time aspect plays a crucial character in the expansion of art. A man's inner potentialities are realised through art. There is an exceptional place & crucial character to engage in recreation in every religion. Religion and art are correlated to each other. Religion has always been a source of stimulation for people since ages. Religion has been a turning point in man's civilizational demonstration since the beginning. Various art forms such as painting, calligraphy, sculpture-making, music, poetry & architecture are motivated by intense religious consciousness. Religion and art have engraved special effects on human civilisation in prehistoric, medieval and modern epoch. (Schimmel)

1. Islam

The religion of Islam spread with electrifying speed from the oasis cities of Medina and Makkah Islam continues to grow not only in Africa but in Europe and America. The global Islamic civilization activated the mind and thought of people. Hence, Islam created ways for people to become torch bearers of science and learning. Islamic civilization spread its extents and with it spread Islamic power, culture, values and principles. The field of Islamic architecture is one of the great examples of rich inheritance of Islamic values in design, planning, art and architecture. Islamic architecture demonstrates the personification of Islamic values through the local and regional genius which was achieved by exploration of various styles and forms of Islamic values. (Calligraphy in Islamic art)

1.1 Islamic Art wih focus on Islamic Calligraphy

Islam is one of the greatest religions of the world. Its approach to life is distinct and different from other religions such as Buddhism, Christianity, Hinduism, etc. Islamic art is seen in varied forms such as calligraphy, architecture, painting, poetry, decorative art & miniature art. Although Islamic art was an outcome of many centuries, it emerged at the same time with the

rise of Islam. There is a connection of Islamic art with Islamic spirituality & hence it is thought of as a heavenly reality on earth. The development of sophisticated calligraphy as an art form is not unique to Islamic culture alone. This is seen in Chinese & Japanese language, Bible inscriptions in North West Europe, etc. But it is used to a much greater extent in the Islamic world and in astonishingly varied and imaginative ways. This has taken the written word far beyond pen & paper into many art forms and materials. This can be used as one of the reasons to say that calligraphy is an original feature of Islamic Art. The field of Islamic calligraphy is almost inexhaustible. The Arabic language is held in great esteem because Quran was revealed and written in this language. The word Islamic is used with calligraphy to symbolise the spiritual foundation that is behind Arabic script. For Muslims, the function of calligraphy is to support and strengthen the spiritual edifice of faith. (George, 2010)

Calligraphy comes from Greek words Kallos (beautiful) and Graphes (writing) and it refers to the harmonious and adequate proportion of both letters in words and words on page. This art form looks effortless because of the flow and proportion but each letter is the result of measurements and multiple marks. The very first script of Islamic calligraphy was Kufic script. Other scripts include floriated Kufic, plaited Kufic, Naskh, Thuluth, Muhaqqaq, Rayhani, Tawqi, Nastaliq, Maghribi, etc which are shown in Figure 1.

1. **Kufic** – The name comes from the Iraqi town of Kufa. It is characterised by angular shapes, broad vertical strokes and extended horizontals written on horizontal baseline. The stiff character of this script did not permit it for ordinary use and was reserved for writing in Holy Quran, inscriptions on stones and coins. Very few people could read it and only professional calligraphers could transcribe it. A few examples of this script are seen in 12th century monuments in India like Quwwat-ul-Islam mosque and Tomb of Iltutmish.
2. **Naskh** – It is a round script. It is characterised by descending letters, heavy and light strokes with equal division between flat and round shapes, letters are fluid, small and neat. The letters are slightly bent towards left and this script is clear, highly legible and easy to write. An example of this script can be seen in Alai Darwaza, India.
3. **Taliq (hanging together)** – This script was mainly used for official correspondence in royal court for writing books and letters. It is characterised by wide spaces between lines, descending strokes which appear as loops and rounded letters. The lines ascend as they move right to left.
4. **Nashtaliq** – It was originally devised to write non-Quranic works and literary works in Persia, India and Pakistan. It is characterised by short vertical strokes, horizontal strokes, varying thickness of letter shapes and deep hook like letters. It can be seen in Hakim Mosque, Isfahan.
5. **Thuluth** – It means one-third and it was sued for writing different kinds of texts, particularly tiles and inscriptions. It is characterised by vertical strokes with left slant and interlaced letters. It can be seen in Taj Mahal, India.
6. **Riq'aa** – This script is often written on small pieces of paper to petition royalty. It was used for writing letters, epics, stories, etc.
7. **Divani** – It was used to write official documents. It is characterised by wide spaces between lines. The empty spaces in the script are filled with dots. (Baig, 2016)

Fig.1. The Kufic script (top left), The Naskh script (top centre), The Riq`aa script (top right), The Nashtaliq script (left middle), The Taliq script (bottom left), The Thulut script (bottom centre) and The Divani script (bottom right).

Calligraphy as an art was seen in design of carpets, wall hangings, paintings, pots & vases, decorative plates, walls, entrances & gateways, paper, Quran, Islamic books, etc as seen in Figure 2 and Figure 3. Calligraphic designs were created out of many different materials. Ink on parchment or paper, ceramics, wood, stained glass, textiles, enamelled lass, metal, plaster, mosaic tiles etc. were used by Calligraphy artists. Calligraphy as a decorative art developed due to several factors.

Fig.2. Islamic calligraphy on vases (left), Plates (centre) and coins (right).

Fig.3. Islamic calligraphy on niches (left and centre) & armour helmet (right).

The following verses from Quran indicate special significance to the use of pen (a symbol of knowledge), “Read! Your Lord is the Most Bounteous, who has taught the use of pen, taught man what he knew not” (Quran 96: 3-5).

The above verse indicates that calligraphy was not used merely for decorative purposes but also to worship and remember Allah. Arabic calligraphy mainly uses Quranic verses which are used/said in the act of worship, or contain supplications, or describe the character of Allah & His Prophet.

2. History of Calligraphy in Islamic architecture

The Arabic language was the language in which the Quran was revealed, and it hence holds a very important status in the lives of Muslims. During Muhammad's time, Arabic script was a practical and simple means of writing. As Islam spread from Arabia to non-Arabic speaking lands, the Arabic script was revised. Diacritical marks and dots were added to distinguish alphabets. The Dome of Rock is one of the oldest examples which include the early calligraphy masterpieces as shown in Figure 4.

Fig. 4. Quranic inscriptions in Dome of Rock, Jerusalem

The tradition of using calligraphy in art and architecture spread across the continents and finally reached India. Calligraphy has been a very respectable art form and India has a glorious heritage of calligraphy use.

3. History of Calligraphy in Indian History

Muslims entered India during the 11th century and brought with them Islamic values, principles, culture, art and architecture. The official languages were Arabic and Persian during the Muslim Rule. This led to a progressive development of Arabic calligraphy and it was encouraged and patronised by the rulers, nobles and local people because Arabic was sacred to them. Arabic calligraphy acquired a sublime reputation for being artistic, pure, divine and moral representation of Islamic faith in the form of Art. There are rules which govern the use of scripts and writing techniques which are researched upon by calligraphers. The entire calligraphic culture is valued as a part of heritage of Islamic world. The very first examples of Arabic calligraphy were seen on the Quwwat ul Islam mosque and Qutub Minar during Delhi Sultanate. This legacy continued to next dynasties. The Mughal dynasty brought in various new ideas and influences from past to incorporate in buildings. Babar, Humayun and Akbar played a great role in increasing the amount of cultural heritage and artwork in terms of calligraphy and architecture. They built many buildings across North India and a few examples are studied below from Agra and New Delhi. (Inida)

4. Case Studies

4.1 Qutub Minar

Qutub Minar was a victory tower whose foundation was laid by Qutubuddin Aibak. Aibak completed the first level of tower and Iltutmish built an additional two storeys and began the fourth. The remainder of fourth storey and fifth storey were built by Firoz Shah Tughlaq. There are calligraphic bands encircling the plain, fluted exterior of Minar in Naskh script. Each stroke made by calligraphers depict different meaning. It majorly depends on the person as to how he

interprets the meaning from it. The calligraphic bands are bordered with floral designs and patterns. Kufic, Naskh and Thulut styles can be seen in this minar as shown in Figure 5. (Das)

Fig. 5. Islamic calligraphy on Qutub Minar done in Naskh, Kufic and Thulut script.

4.2 Qila e Kuhna Mosque

Shershah Suri did some marvellous architectural works during his reign including Qila-e-Kuhna mosque at Delhi. There is a stark contrast in the prayer hall as it is embellished with red sandstone and white marble as shown in Figure 6. There are fine Quranic inscriptions and white marble inlay work. Surah Al-Fatiha (Surah-48) is engraved at the jamb of central arch. The first two verses are on white marble framed with a border of geometrical pattern. The text of the third verse of the Surah is continued on red sandstone surrounded by floral pattern which is further bordered with a strip of black stone. The last two verses are inscribed on white marble on the other side. Another arch is embellished with Surah Al-Mulk (Surah-67), inscribed all in red sandstone. Architrave bears 20 verses of Surah Al-Muzzammil (Surah-73). In the interior of mosque all bays have decorative niches in qibla wall. The calligraphy style used in this mosque is Naskh. The architrave of southern mihrab bears the four verses of Surah Al-Hashr (Surah-59) while arched calligraphy contains Surah Al-Fil and the script is in Muhaqqaq style. The mihrabs seems to be the work of a different calligrapher as it has Kufic inscription of Kalima Tayyiba carved in white marble. (Asif Ali, 2017)

Fig. 6. Quranic inscriptions in Qila e Kuhna Mosque, Delhi

4.3 Buland Darwaza

Emperor Akbar built a new city on small hillock at Sikri and shifted his capital from Agra in the second half of the Sixteenth century. The city was built on arcuated system except the mosque, and tomb of Salim Chishti, a native saint of Sikri. Akbar built a victory gate known as Buland Darwaza, a south entrance to the great mosque of Fatehpur Sikri after conquering Gujarat. The gate has beautiful inscription in carved relief work on sandstone. The calligraphy is in Thuluth script and the inscription is from the Surah Az-Zumar(Surah-39).

Figure 7. Islamic calligraphy on Buland Darwaza in Fatehpur Sikri.

4.4 Akbar`s tomb

Akbar finalised the plan of his tomb, but his son Jahangir made many changes to it later. The inscriptions are in both in Persian and Arabic languages. It contains the praising words for emperor, modified quotations from Quran and on the last panel name of the calligrapher, Abdul Haq Shirazi with date. The inscription is carved on white marble with Thuluth script as shown in Figure 8. The inner grave chamber has no inscription with plain cenotaph of the emperor. Vestibule before grave chamber has a long calligraphic band near ceiling in golden colour with blue background in stucco. The inscription is in Thuluth script having portions from Surah Al-Mulk (Surah-67), Surah Al-Ahzab (Surah-33) and Surah As-Saffat (Surah-37).

Figure 8. Calligraphy in Akbar`s tomb, Sikandra

4.5 Taj Mahal

Taj Mahal is not only famous for its composition of masses and the material but it's well versed decoration with arabesques, geometrical patterns and calligraphy. Amanat Khan Shirazi was the calligrapher of Taj Mahal. Most of the inscriptions in Taj Mahal are Quranic verses unlike in Akbar`s tomb where there is more Persian calligraphy. It is presumed that the selection of verses and surah to be inscribed on the monuments was done by the calligrapher.

Figure 9. Islamic calligraphy in Taj Mahal, Agra

The calligraphy at Taj looks well-coordinated with its plan and elevation so that the inscriptions become integrated part of the scheme. The themes of the selected passages of Quranic verses are about the day of judgement, paradise for the true followers, rewards to the faithful and divine mercy of Allah. The black calligraphic verses are inlaid into the white marble. The first 21 verses of Surah Yaseen (Surah-36) are inscribed on the southern gateway to the tomb. The calligraphy at Taj Mahal is the climax of the art work in the Mughal architecture. (Asif Ali, 2017)

4.6 Jama Masjid

Shahjahan shifted his capital from Agra to Delhi in 1638 and planned a new city named Shahjahanabad. The Jami Masjid was proposed near bazaar to serve the population of the city. The medallions bear one of the names of Allah 'Ya Hadi' repeated eight times and arranged in radial fashion so that 'Alif' makes an octagonal star at the centre. In the same way the spandrels of arch at the central mihrab bears a medallion of other name of Allah 'Ya Ghaffar". They are written in Tughra design of Thuluth script. All the ten small arches have inscriptions above on white marble panels inlaid with black stone. They bear information regarding the history of building, construction duration, cost, name of builder and calligrapher. These panels bear Persian prose and Quranic verses. On the central mihrab verses from Surah Az-Zumar (Surah-39) and

Surah At-Tawba (Surah-9) are chosen very wisely for the occasion as they explain the significance of mosque for the believers and mercifulness of Allah. The name of the calligrapher mentioned as Nur Allah Ahmad at the lower left of the last panel on the southernmost side. (Asif Ali, 2017)

Figure 10. Calligraphy in Jama Masjid, Delhi

5. Contemporary study

The use of Islamic calligraphy in olden times served various purposes. These were interpreted differently by different people. Arabic calligraphy can be seen in varied forms and styles today. It can be seen in Art, architecture, lighting, sculptures, paintings, wall decals, frames, vases, decorative plates, wall hangings etc. The trend has been kept intact and is further modified and implemented in the above-mentioned fields. There are many modern scripts which have evolved with time and modern calligraphers use these to create art in a modern manner.

Figure 11. Use of Calligraphy in Qatar faculty of Islamic studies centre

Figure 12. Use of Islamic calligraphy as a sculpture (left), in lamp design (centre) and as graffiti (right).

Figure 13. Use of Islamic calligraphy as Wall frames (left), in building façade (centre) and staircases (right).

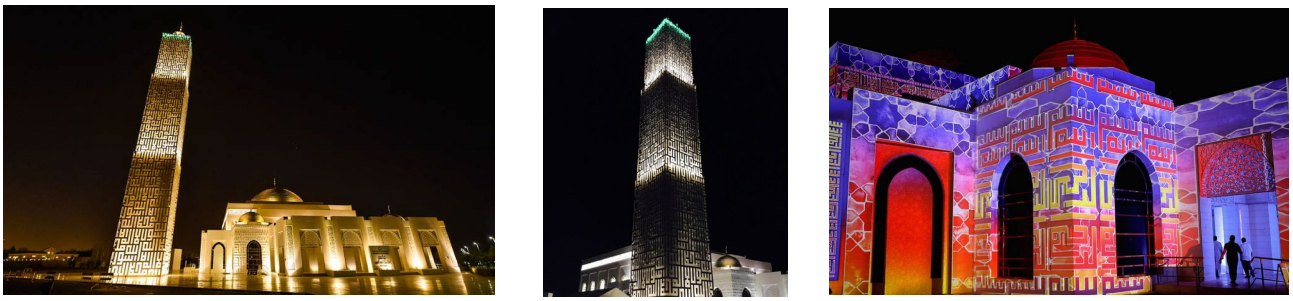

Figure 14. Use of Islamic calligraphy in Al Ghurair Mosque, Dubai.

6. Conclusion

Arabic calligraphy developed with the revelation of Quran and reached highest level of art and embellished several Islamic monuments throughout the world. In India this art was developed and promoted by Muslim rulers and reached at its zenith during Mughal period. Today it is in use in advertising, maps, logos, wedding invitations, other types of invitation cards, pamphlets, props, posters, book covers, poetry collections, children books, religious sculptures etc. and executed on paintings buildings, textiles, and industries. Contemporary calligraphers produced beautiful specimens and designs of calligraphy not only in India but all over the world. The ancient research behind calligraphy helps the architects to design proportionate and justified calligraphy type in modern buildings as it is still associated with Islamic architecture. The architects today still use the old techniques and practices to keep connected to their culture, though in a modern manner. The contemporary buildings like mosques, offices, museums, sculptures etc use Arabic inscriptions or alphabets to form unique jail patterns and facades. This can be seen in many buildings in gulf countries. The purpose of using Arabic calligraphy is more because of the aesthetics. But, this can be made more meaningful to people and public realm. This paper talks about the history of Islam, Islamic Art, Islamic Calligraphy and its significance today. This aspect of Islamic Art can be taken to much higher levels and heights by more meaningful abstraction and implementation of the same as before.

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Concrete filled tubular elements with dismountable joints bearing capacity determination

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Abstract – In the article the method of determining the bearing capacity of the dismountable joints of concrete filled tubular elements is presented (in particular elements with a flange joint, joints with longitudinal ribs and steel coupling joint). With the help of the above algorithm, the diagrams of the bearing capacity of the dismountable joints are constructed. Comparison was made to determine the most optimal joints from presented.

Keywords – concrete filled tubular elements, bearing capacity, dismountable joints.

Introduction

Originating as building constructions about a century ago, concrete filled tubular structure has recently become increasingly widespread in a variety of construction sectors including civil and industrial construction [1–11]. This is explained by the successful combination of properties of steel and concrete, due to which concrete filled tubular structure have high strength, reliability, durability, meet high-tech requirements at relatively low material costs. However, the most important and difficult task for the design of concrete structures is the question of the implementation of joints. Often in particular during mounting large bending moments occur in the joints. In the given work the method of determination of bending moments and comparatively different types of dismountable joints of concrete filled tubular elements for bearing capacity and materials costs are offered (on the example of calculating the connection for a real building of a shopping and entertainment center).

The Results of the Development

Based on the hypothesis of Bernoulli (hypotheses of plane cross sections), in particular the thesis on the equality of deformations within an element and on its surface, we will define the main characteristics of the stress-strain state on the example of concrete filled tubular element with a diameter of 108 mm and a wall thickness of 4 mm. To do this, follow the steps below:

1. Break down the concrete element into 27 equal sections (Fig. 1) and define their geometric parameters (in particular, the area of the site and the position of the center of gravity) using the formulas 1–4.

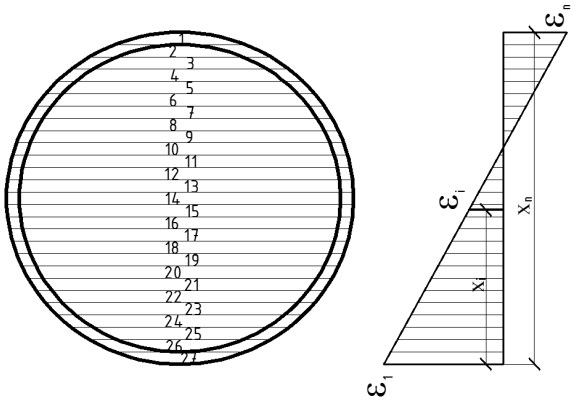


Fig.1. The investigated concrete filled tubular element is divided into discrete plots

The total area of 1 plot was determined by the Eq. 1:

$$A_{c,seg\,i} = 0{,}5r^2 \cdot (\pi \cdot \alpha / 180 - \sin(\alpha)) \quad (1)$$

α – angle of the arc of *i*-th segment.
r – arc radius of *i*-th segment.
The area of the steel pipe, for the corresponding *i*-th segment:

$$A_{s,seg\,i} = 0{,}5R^2 \cdot (\pi \cdot \alpha / 180 - \sin(\alpha)) - 0{,}5r^2 \cdot (\pi \cdot \alpha / 180 - \sin(\alpha)) \quad (2)$$

The area of the *i*-th concrete segment:

$$A_i = A_{seg\,i} - A_{seg\,i-1} \quad (3)$$

Coordinates of the center of gravity:

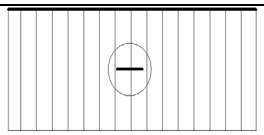
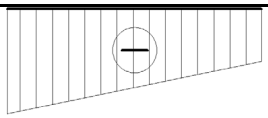
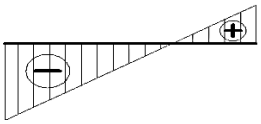
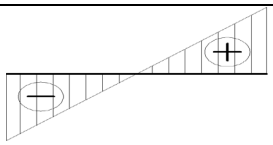
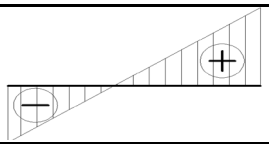
$$y_i = (2 \cdot r \cdot \sin(\alpha/2))^3 / 12 A_{c,seg\,i} \quad (4)$$

As the boundary conditions for the first and last plots (Table 1) deformations were made corresponding to the deformations of the yield strength of the steel (compression for the first section, bend for the last). By Eq. 5 deformations were determined for each *i*-th section (Fig. 1).

$$\varepsilon_i = (\varepsilon_1 - \varepsilon_n) / x_n \cdot x_i + \varepsilon_n \quad (5)$$

Table 1

Boundary conditions for constructing *N–M* diagram

№	ε1	εn	Curve of deformation
1 (central compression)	-fy/E	-fy/E	
2	-fy/E	-0,5fy/E	
3	-fy/E	0,5fy/E	
4	-fy/E	fy/E	
5 (bend)	-k×fy/E	fy/E	

Based on the values of the deformations of each i-th section, the corresponding values of stresses for each of the sections (individually steel and concrete) were calculated according to Eqs. (6), (7) and (8):

$$\varepsilon_i \geq \varepsilon_{c3}, \qquad \sigma_c = f_{cm} \quad (6)$$

$$\varepsilon_i \leq \varepsilon_{c3}, \qquad \sigma_c = E_{cm} \cdot \varepsilon_i \quad (7)$$

$$\varepsilon_y \geq f_y, \qquad \sigma_y = E_s \cdot \varepsilon_i \quad (8)$$

After that, there was a transition from the stresses in each of the segments to the values of the longitudinal force and the moment carried out by the Eqs. (9), (10), (11) and (12):

$$N = \sum_{i=0}^{n} \sigma_i \cdot A_i \qquad (9)$$

$$\sigma_{m,i} = \sigma_i - \left((\sigma_{i,\max} - \sigma_{i,\min}) / 2 \right) \qquad (10)$$

$$N_{m,i} = \sum_{i=0}^{n} \sigma_{m,i} \cdot A_i \quad (11)$$

$$M == \sum_{i=0}^{n} \sigma_{m,i} \cdot A_i \cdot y_i \qquad (12)$$

For the results of calculating the longitudinal force N and the bending moment M, a diagram of the bearing capacity of the concrete filled tubular column (Figure 2) with a diameter of 108 mm and a wall thickness of 4 mm was constructed (sample TB-1). The proposed algorithm is automated and presented as a simple to use program. To check the bearing capacity of a concrete filled tubular sample, it is necessary to compare the location of the combination of external loads with the constructed bearing capacity curve, in the case where the combination of loads does not extend beyond the load-bearing curve, the ability of the element is secured.

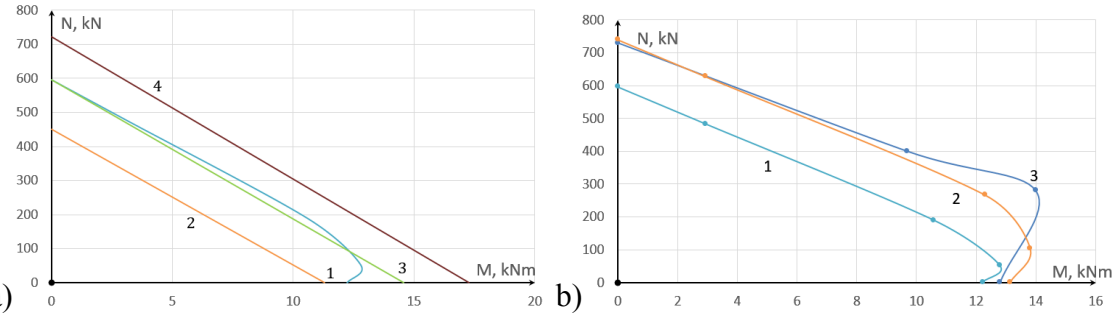


Fig.2. Diagram of bearing capacity *N–M* compared with: a) reduced curves and b) experimental curves

For the final verification of the diagram of the bearing capacity (1) in Fig. 2a shows the diagram of the bearing capacity of a steel pipe without concrete filling (2), a diagram of the bearing capacity of the concrete filled tubular element, where the concrete is reduced to steel by the ratio $\delta = f_{ck} / f_y$ (3) and the diagram where the concrete is brought to the steel by the ratio $\delta = E_{cm} / E_s$ (4). In fig. 2, b is a comparison with the diagram, which takes into account the effect of compression of concrete by a steel pipe (2), and a diagram built on the basis of experimental studies of a similar sample (3). Analyzing the obtained curves, it can be concluded that the reserve bearing capacity is 20% is in the case of compression with zero eccentricity, since the effect of compression of concrete by a steel pipe in this case was not taken into account.

To construct a similar diagram of bearing capacity for an element with a joint, it is necessary to determine the product of the complete longitudinal force for each area located in the stretched zone of the concrete filled tubular element on the corresponding shoulder from the boundary line to the center of the plot (Figs. 3 and 4). It is necessary to consider that for the load combinations, which are to the left of the boundary line 1 (Fig. 3), the total stretching moment

will be equal to zero, therefore, the size of the joints elements from the conditions of tension can be taken based only on constructive requirements.

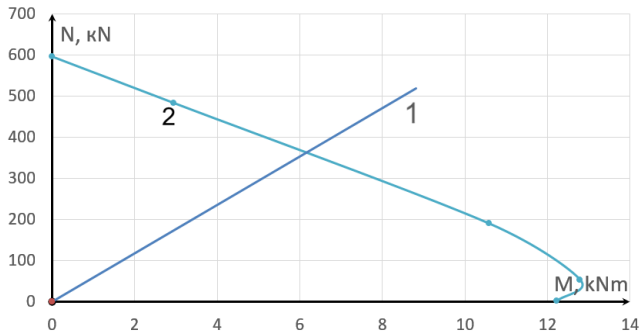


Fig.3. The line of constant eccentricity, which shows the appearance of stretching forces at the joint (1) and the curve of bearing capacity *N–M* (2)

For calculating the concrete filled tubular elements from the combinations of external forces located to the right of the boundary line 1 (Fig. 3), it is necessary to calculate the total stretching torque as the product of the tensile strength for each section of the section for the corresponding distance (Fig. 4) from the boundary line to the center of this section $\sum(N_t \cdot z_t)$. The value of this product will vary in proportion to the entire line of action of constant eccentricities 1 (Fig. 3). Therefore, calculating the total stretching torque $\sum(N_t \cdot z_t)$ for points on the diagram of the bearing capacity of *N–M*, it becomes possible to calculate this moment for any combination of external loads. It is necessary to consider the fact that if during constructing the joint for all combinations of loads the location of which is outside of the diagram 2 (Fig. 3) then the bearing capacity of the received concrete filled tubular element is insufficient and it is necessary to increase the diameter of the element or the thickness of the steel pipe.

Figure 4 is a diagram for determining the total stretching torque for the dismountable joints of concrete filled tubular elements with longitudinal ribs. After definition $\sum(N_t \cdot z_t)$ we can use the well-known formulas for calculating bolts and flanges for the final construction of the joint.

Calculation of the cross section for the action of transverse force:

$$\sigma = Q / A_{\text{sec}\,tion} < f_y \qquad (13)$$

Calculation of bolts:

$$N_b = \sum(N_t \cdot z_t) / z_b \le N_{bs} \qquad (14)$$

$$N_{bs} = R_{bs} A n_s \gamma_b \qquad (15)$$

$$N_{bp} = R_y d \sum t_{\min} \gamma_b \qquad (16)$$

Calculation of the longitudinal ribs of the joint:

$$N_r = A_r \cdot R_y \ge N_b \qquad (17)$$

$$\sigma = M_{\max} / W_r \le f_y \qquad (18)$$

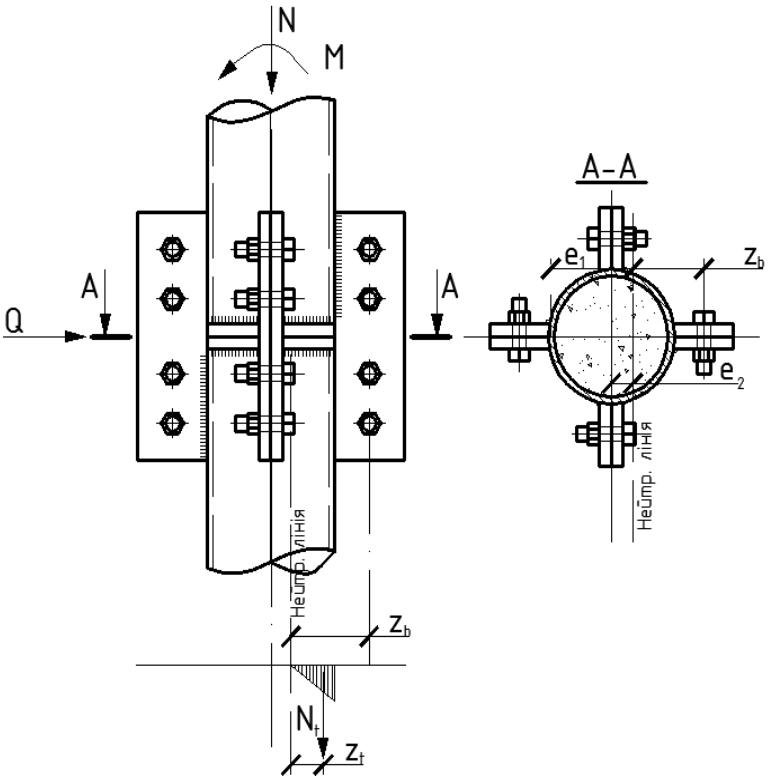


Fig.4. Dismountable joints with longitudinal ribs

Using the above methodology, Figure 5 shows a diagram of the bearing capacity of a joint with longitudinal ribs, where 1 is a diagram of the bearing capacity of concrete filled tube with a diameter of 108 mm and a wall thickness of 4 mm. The combinations of external loads *N* and *M*, which are within the curve 1, satisfy the conditions of the bearing capacity of the pipe concrete element; 2 – diagram of bearing capacity of 16 bolts with a diameter of 12 mm applied in the connection, a combination of external loads *N* and *M*, located above line 2, are permissible from the condition of the bearing capacity of the bolts; 3 – diagram of the bearing capacity of concrete filled tubular elements with longitudinal ribs of 200×60×10 mm, similar to curve 1 of the combination of external loads *N* and *M*, which are within the curve 1, satisfy the conditions of bearing capacity.

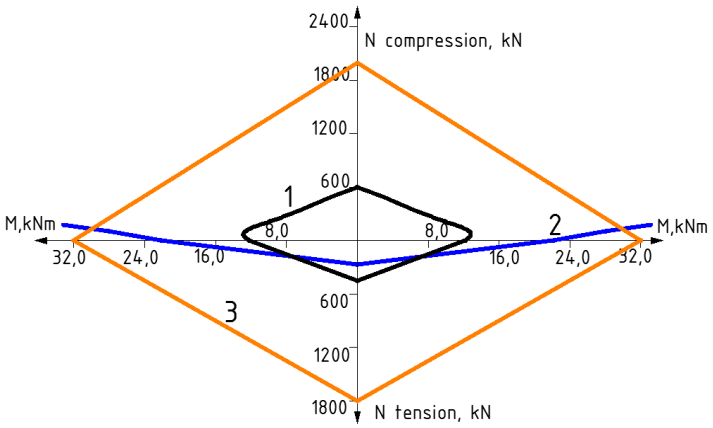


Fig.5. Diagram of bearing capacity of dismountable joint with longitudinal ribs

Similarly, a diagram of bearing capacity for a dismountable flanged joint was constructed, which is shown in figure 6, where 1 is a diagram of the bearing capacity of a concrete filled tubular elements with a diameter of 108 mm and a wall thickness of 4 mm. Combinations of external loads *N* and *M*, which are within the curve 1, satisfy the conditions of the bearing capacity of the concrete filled tubular element; 2 – diagram of bearing capacity of 4 bolts with a

diameter of 12 mm applied in the connection, a combination of external loads N and M, located above line 2, are permissible from the condition of the bearing capacity of the bolts.

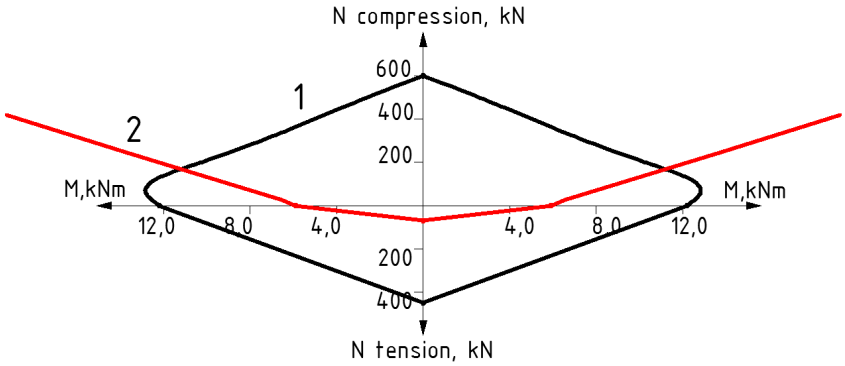


Fig.6. Diagram of bearing capacity of dismountable flanged joint

The stretching force in the bolt is determined by the formula:

$$N_b = \sum (N_t \cdot z_t) \Big/ 2 \cdot z_{b2} \qquad (19)$$

The bolts are checked for tension and for the cut according to the Eqs. (14), (15) and (16). The thickness of the flange is checked based on the following formulas:

$$t_{\min} \geq \sqrt{6M_1 \Big/ bR_y\gamma_c} \qquad (20)$$

$$t_{\min} \geq N_{bp} \Big/ R_{bp} d\gamma_b \qquad (21)$$

Figure 7 shows the diagram of the bearing capacity of the dismountable joints of the concrete filled tubular elements executed with the help of a steel coupling, where 1 – similar to the previous joints, the diagram of the bearing capacity of concrete filled tubular element with a diameter of 108 mm and a wall thickness of 4 mm; 2 is a diagram of the bearing capacity of a steel coupling 2.5 mm thick and an internal diameter of 108 mm, combinations of external loads of longitudinal force N and bending moment M, which are above this line, satisfy the conditions of bearing capacity for the given coupling. The tension in the coupling connection was determined by the formula proposed by G. Lame for the bushing connection:

$$\sigma_2 = \alpha_0 \cdot G \Big/ (D_m - D) \cdot h \leq R_y \quad (22)$$

G – external force on the steel coupling which is defined as the ratio of the tensile moment $M_{\max}$ up to half the coupling height h:

$$G = M_{\max} \Big/ 0{,}5h \quad (23)$$

The section of the element was also tested from the conditions of the transverse force according to the Eq. (24)

$$\sigma_1 = Q \Big/ A \leq R_y \quad (24)$$

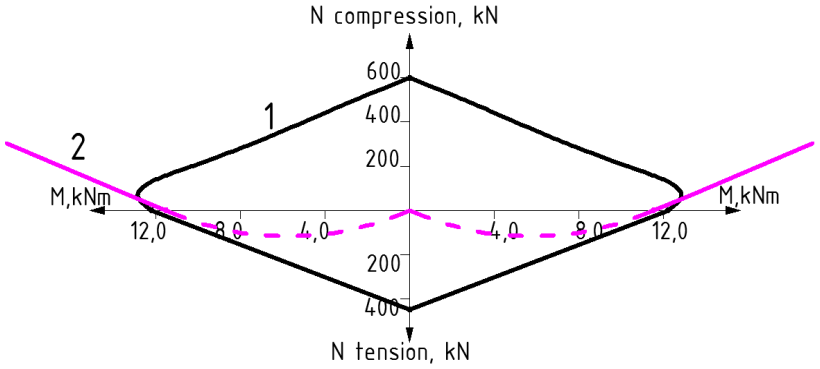


Fig.7. Diagram of bearing capacity of dismountable joint with a steel coupling

A study was conducted for a real building of a shopping and entertainment center with tube columns with an external diameter of 426 mm and a wall thickness of 8 mm in order to compare and determine the most optimal joint from the conditions of load bearing capacity and material costs. The comparison was carried out for identical loads, namely, the longitudinal force N = 1700 kN and the bending moment M = 350 kNm. Determination of bearing capacity and dimensions of joints was carried out using the above methodology. Table 2 shows the results of materials consumption for 1 joint for each type of joints (with a flanged joint – Fig. 8, a joint with longitudinal ribs – Fig. 9 and a coupling connection – Fig. 10) from conditions of identical bearing capacity. The least cost was found for a dismountable joint with longitudinal ribs, which suggests that for this building, this option is the most optimal.

Table 2

Cost of steel for the manufacture of 1 joint

Expenses of materials	Flanged joint N=1700 kN M=350 kNm	Joint with longitudinal ribs N=1700 kN M=350 kNm	Joint with steel coupling N=1700 kN M=350 kNm
Steel, kg	81,7	37,7	43,2
Bolts, pc	8Ø24	16Ø16	4Ø12
Weld seams, mm	2670	3470	4040

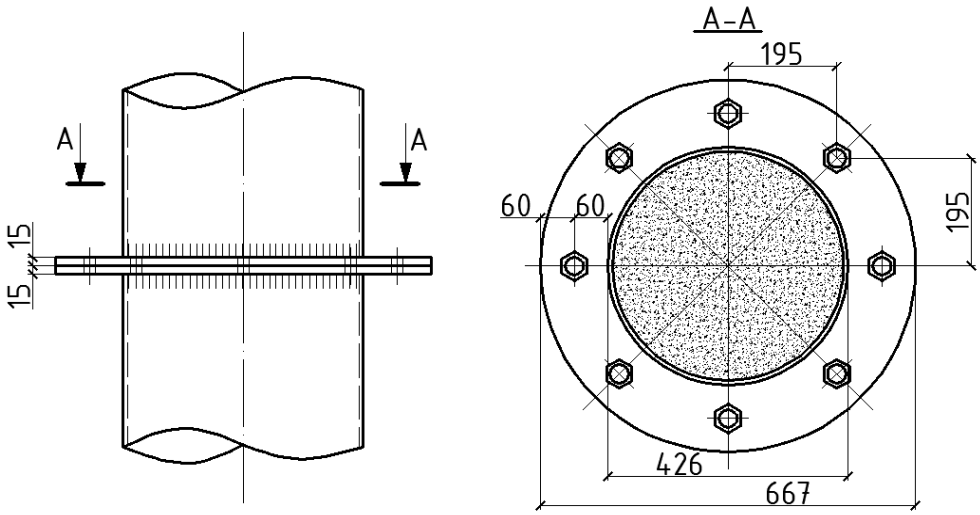


Fig.8. Flange joint of concrete filled tubular elements for the considered combination of loads

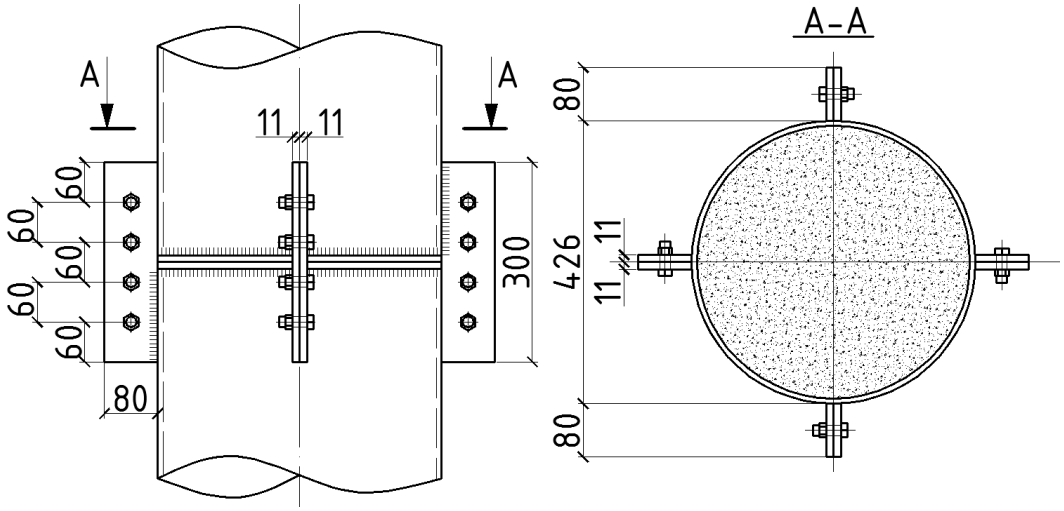


Fig.9. Dismountable joint of concrete filled tubular elements with longitudinal ribs for the considered combination of loads

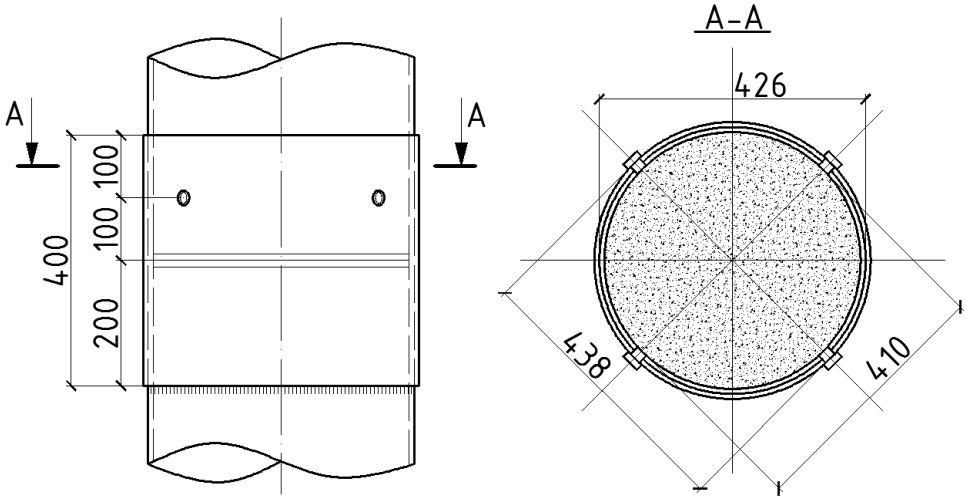


Fig.10. Dismountable joint of concrete filled tubular elements with steel coupling for the considered combination of loads

Conclusion

The article presents the algorithm for determination of bearing capacity of concrete filled tubular elements and their joints by constructing *N–M* curves. The method of determining the bearing capacity of the elements of the dismountable joints is proposed and a comparison was made for the building of the shopping and entertainment center, and it was found that for this case, the construction of the joint with longitudinal ribs is the most optimal.

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Methodology for the territories' engineering construction assessment with difficult geological conditions

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Abstract – The methodology for the territories' engineering construction assessment of Kalush city with particularly complicated geodynamical and geoecological conditions was appended. Four categories of sites with different levels of suitability for construction were allocated, including useless city's sites for constructions, which require primary urgent reclamation measures.

Keywords – construction assessment, estimated factors, geodynamic processes, geomorphological districts, geotechnical properties, karst and suffosion, planning restrictions, rocks' deformation, complexes' group of soils, construction sites.

Introduction

Existence methods of engineering geological zoning are unable to provide the basic information completely about engineering geological conditions of construction sites and their changes during building maintenance [1]. This is related to inadequate level of engineering geology's methodological questions processing and engineering geological zoning. Value and the nature of negative influence of geological processes phenomena are defined by numerous local natural particulars of geological environment [2]. Besides, technogenic modification of geological environment in the cities *is being transformed by the influence* of productive use, which resulted in changes of local engineering geological conditions [3]. An engineering construction assessment is an effective method of territory's assessment reflecting all necessary engineering and hydrogeological conditions, monitoring natural and technogenic processes, analyzing geomorphological and tectonic particularities of construction [4]. This procedure verifies to select sites with different levels of suitability for construction.

The ERS data will be used for natural and technogenic geological processes' monitoring to improve the quality of assessment. This paper was written as a result of scientific and design work of the State Enterprise "Scientific Research and Design Institute of Urban Development" (Kyiv) under conservation master plan of Kalush in accordance with the treaty № 2017-107 on 21.09.2017 with executive committee of the Kalush city council. The results of this article will inform the development of engineering construction assessment's and territory protection safety schemes.

Theory and methodology

Kalush city of Ivano-Frankivsk region is one of the extraordinary environmental situation zone of Ukraine. The environmental balance in the rock's fatter of the Kalush-Holyn potassium salt's deposit was violated as a result of chemical enterprises' illiterate economic activity. Numerous Earth's surface failures above mine fields' area, destruction of buildings and communications, salinization of aquifers in the city resulted from adoptions of the wrong decisions concerning mining, location and operation TMFs, tips, accumulation tanks and methods for disposing mine voids.

The initial data for assessment engineering geological zoning are: reports of the State Enterprise "Ukrgeophysics" [5], Halurgy Research Institute [6, 11], geological map of Kalush-Holyn potassium salt's deposit and its geological and surveying section, reciprocally incorporated plan of Kalush mine from industry association "Chlorinevinyl", geotechnical reports for inhabited and industrial construction on the territory of Kalush city [7].

Two large geomorphological districts was allocated on Kalush's territory in accordance with the geomorphological scheme of Ukraine [8], there are Kalush plain and Voinyliv heights. These natural geomorphological districts were additionally elaborated in detail by allocation of slopes with various degrees of gradient within each of them. The map of slope gradient was created by using 3D Analyst tool in ArcGIS ArcMap 10.0 software product. Such categories have been allocated according with slopes' steepness classification [9] for construction development: 1) very gentle (2-5°); 2) gentle (5-10°); 3) average gradient (10-15°); 4) steep (15-29°); 5) very steep (30-45°). The flood's line 1% map was provided with limits of all river's inundated lands in Kalush by Galitsky Interdistrict Water Authority, this made it possible to allocate one more geomorphological district. Gully network have been allocated in the topographic map (scale 1:10000) provided by executive committee of the Kalush city council. Nine natural geomorphological districts in Kalush have been allocated on the basis on gradient slopes' map and topographic map provided by these organizations.

Technogenic landforms have been allocated on Kalush's territory based on R*&D* reports of the State Enterprise "Halurgy Research Institute" [6]: districts X–XXIII. So, the territory of Kalush city was divided into 23 geomorphological districts, which included natural, technogenic relief (Fig. 1). Groundwater's level and complexes' group of soils, which lay first from the surface were identified for each geomorphological district. From 1 to 6 complexes' groups of soils indicating their thickness, lithological composition and geotechnical properties have been allocated inside of each geomorphological district during the analysis of R*&D* reports' data. Geotechnical properties of some soils are not suitable for construction and these soils with such properties intended to be low-load-bearing soils [10].

Flooding and inundation are true for floodplains of rivers, streams and gully network. Besides that, floodplains of small rivers and streams, as is the case in Kalush, are not suitable for construction, because they provide protective function for hydrologic ecosystems (art. 80 of Ukrainian Water Code). Steep and very steep slopes of Kalush plain and Voinyliv heights are the potential place of gravitational processes and construction development of such slopes involves the large volumes of groundwork and protective measures. We have, thus, such geomorphological districts assigned to not suitable for construction. All districts with technogenic landforms are also unfit for development, because the dangerous geodynamic processes, aggressive and wick component elements in lithological structure have been characterized for them. Such districts constitute a danger or toxicity for human habitability and are considerable to urgent rehabilitation works. Inundation lands (groundwater level ≤2,5 m), waterlogging (groundwater level ≤0,5 m), sites with high salt mineralization and groundwater's aggressive corrosive effect are aggravating hydrogeological factors.

Ecological and engineering geological planning restrictions and geodynamic processes have been further analyzed for allocation of sites with different suitability degree. Mining taps' limits around mining ventures and subsidence's nil contours relate to engineering geological planning restrictions [6]. Areal of groundwater's salinization and isolated incidents of burial

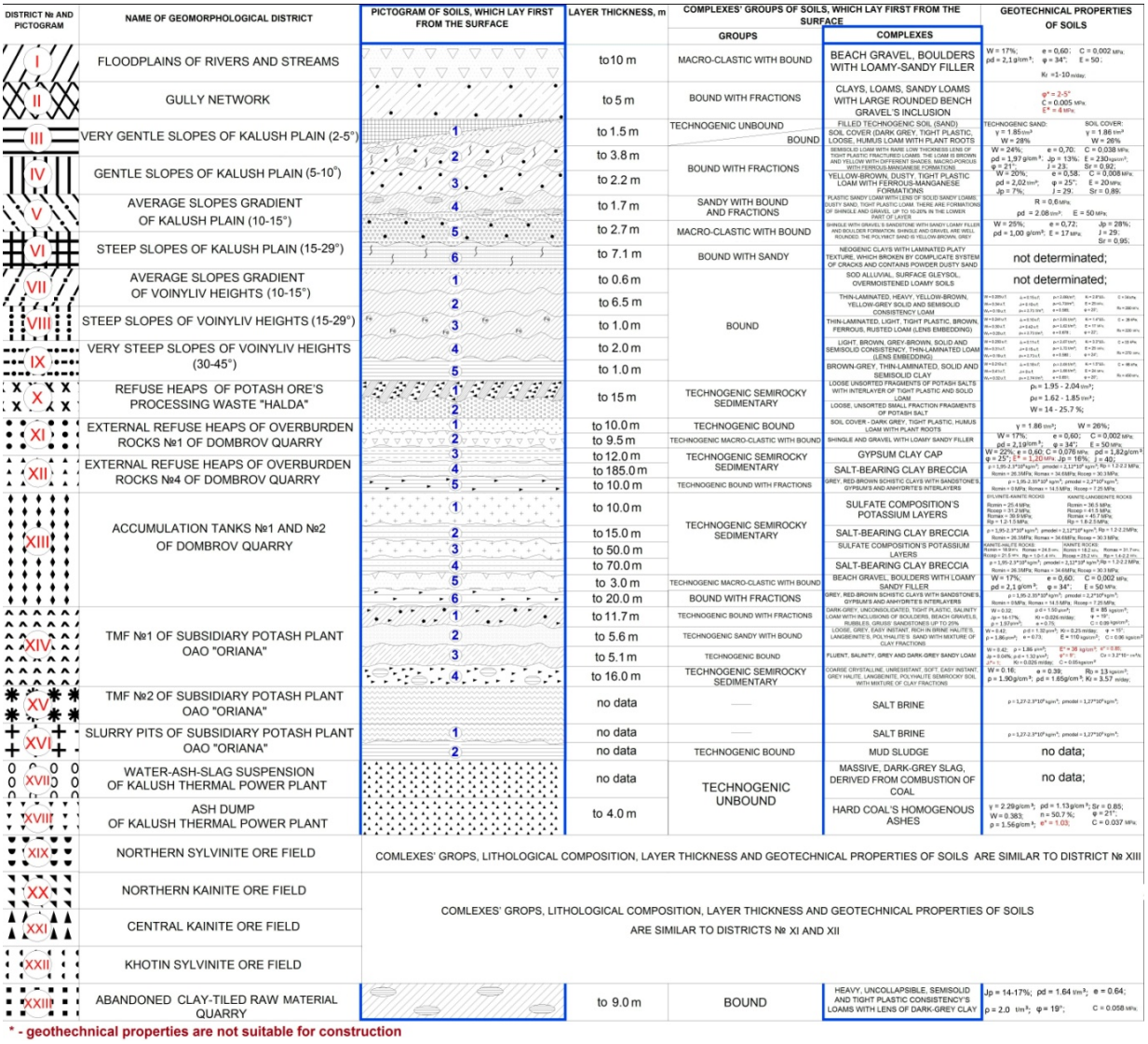

Fig. 1 Geomorphological zoning and engineering geological conditions of Kalush city. Table-legend for the basic assessment map

packing with hexachlorobenzene related to ecological geological planning restrictions. These restrictions signal about primary urgent reclamation and protective measures on whose realization the ecological balance of geological environment of city and the health of him inhabitants in future depends.

Geodynamic processes represent by endogenous and supergene processes. Endogenous explosive tectonic disturbances represent by Kalush and Kropyvnytskyi lines of thrust fault, tectonic scale's route and transverse thrust faults. Tectonic disturbances have a negative influence on sustainability of buildings and structures because geodynamic processes in the Earth's crust contribute to soil's unsealing of sub-foundations. This leads to subsidence of building, formation of fractures in sub-foundatition's walls, damaging of line engineering structures. Tectonic disturbances contribute to seismic increments, which entails material damages and loss of lives. Supergene processes have a high degree of expressiveness on Kalush territory and they included flooding, inundation, salinization of aquifers, corrosive aggressiveness of surface and ground waters, eutrophication, gravity processes, rock's deformations above the underground mine workings, karst and suffosion. Supergene geodynamics is visible by comparison of multi-temporal space images (Fig. 2).

Dynamics of karst sinhole (2005, 2013, 2017)

Example of Earth's subsidence and waterlogging (2005, 2013, 2017)

Dynamics of Dombrov quarry's inundation by salt brines. Increased area of water table from 25 ha to 86 ha for 12 years (2005, 2015, 2017)

Fig. 2 Technogenic processes' dynamics of Kalush city on multi-temporal space images

Justification of estimation scales and units of assessed indexes' is an important stage of engineer construction assessment's method of any territory. There is no single estimation scale for morphometrical indexes of karst relief's assessment.

We propose following: each geomorphological index would be estimated for construction development regarding a four-point scale, where: 0 point means the absence of negative influence, 1 point implies a minimum complexities are easily managed with the preventive measures, 2 points refers an average complexity for building development with necessary engineering protection measures, 3 points represents a very difficult conditions construction with significant increasing costs for construction and also it means that complicated engineering protection measure doesn't guarantee a stabile building maintenance, 4 point indicates that construction in such conditions is impossible or indicates on ecological disadvantage of the territory which entails primary reclamation measures. Geomorphological, ecological, engineering geological, geodynamical and hydrogeological factors were estimated according a 4-point scale.

The points' sum of those estimated factors served as the basis for allocation of building sites with different levels of suitability for construction development: 0 - 3 points – suitable for construction sites; 4 - 6 points – little use for construction sites; 7 - 10 points – useless for construction sites; ≥ 11 points – useless for construction sites, which require primary reclamation (Fig.3).

Conclusions

The main result of engineering construction assessment was an allocation of 4 group's sites with different levels of suitability for construction (Fig. 4):

Sequence number and name estimated geomorphological districts	Estimated factors										
	Geomorphological		Ecological		Engineering geological		Geodynamical		Hydrogeological	Points	Sum of points*
	Slope steepness	Points	Existence of ecological and engineering geological planning restrictions	Points	Existence of low-load-bearing or polluted soils in lithological structure	Points	Existence of geodynamical processes	Points	Dominant of first groundwater layer's depth against the Earth's surface		
1	2	3	4	5	6	7	8	9	10	11	12
I. Floodplains or rivers and streams	0-2°	**1**	Prohibits on lands in floodplains of small rivers and streams for construction aims (besides hydraulic engineering construction) in accordance with 80 article of WCU	**3**	Absence	**0**	Cliffs, flooding, waterlogging, partial salinization of surface and underground water	**3**	0-0,5 m	**3**	***10***
Consequences during construction	Difficulties for overflow system, violation of environmental law of the state and economic sanctions, requirements in large volumes of land development (lowering of water tables, dam construction, embankment walls, clearance of salinization surface waters, requirements in bedding and inwash, loss of recreational areas, shallowing and desiccation of rivers.										
II. Gully network	5-10°	**0**	Absence	**0**	Soils with unsuitable geotechnical properties for construction are present	**3**	Waterlogging, collapses	**2**	1,0-2,5 m	**2**	***7***
Consequences during construction	Requirements in large volumes of land development (territory bedding, introduction of drainage, lowering of water tables, use of pile foundation), degradation of drainage properties of gully network, big risk of waterlogging and eutrophication.										
III. Very gentle slopes of Kalush plain	2-5°	**1**	Absence	**0**	Absence	**0**	Absence	**0**	5-10 m	**0**	***1***
							Eutrophication	**2**	0-0,5 m	**3**	***6***
							Waterlogging	**2**	1,0-2,5 m	**2**	***5***
							Flooding	**3**	1,0-2,5 m	**2**	***6***
							Explosive tectonic disturbances	**4**	3,0-5,0 m	**1**	***6***
			Sites in mining taps' limits around mining ventures	**4**			Groundwater's aggressive corrosive effect on metal constructions and beton	**4**	5,0-10,0 m	**0**	***9***
							Explosive tectonic disturbances	**4**	5,0-10,0 m	**0**	***9***
			Sites with areal of groundwater's salinization	**2**	Absence	**0**	Groundwater's aggressive corrosive effect on metal constructions and beton	**4**	3,0-5,0 m	**1**	***8***
							Explosive tectonic disturbances	**4**	5,0-10,0 m	**0**	***7***
			Sites in mining taps' limits around mining ventures with areal of groundwater's salinization	**4**			Groundwater's aggressive corrosive effect on metal constructions and beton	**2**	3,0-5,0 m	**1**	***8***
							Explosive tectonic disturbances	**4**	5,0-10,0 m	**0**	***9***
Consequences during construction	Very gentle slopes of Kalush plain without geodynamic processes are the suitable for construction territory, the only one disadvantage is the difficult procedure of vertical planning for overflow system. Introduction of drainage, protection hydraulic structures are required for eutrophication and waterlogging territories. Special pile foundations are required for sites with explosive tectonic disturbances. All sites in mining taps' limits around mining ventures with areal of groundwater's salinization are not suitable for construction through high intensification of geodynamic processes and existence of ecological planning restrictions.										
IV. Gentle slopes of Kalush plain	5-10°	**0**	Absence	**0**	Absence	**0**	Absence	**0**	5,0-10,0 m	**0**	***0***
							Groundwater's aggressive corrosive effect on metal constructions and beton	**4**	5,0-10,0 m	**0**	***4***
			Sites with areal of groundwater's salinization	**2**			Groundwater's aggressive corrosive effect on metal constructions and beton	**4**	5,0-10,0 m	**0**	***6***
			Sites in mining taps' limits around mining ventures with areal of groundwater's salinization	**4**			Groundwater's aggressive corrosive effect on metal constructions and beton	**4**	5,0-10,0 m	**0**	***8***
							Explosive tectonic disturbances	**4**	5,0-10,0 m	**0**	***8***
Consequences during construction	Gentle slopes of Kalush plain without geodynamical processes are the suitable territory for construction. Sites with areal of groundwater's salinization belong to the little use sites through the high level of corrosion activity by aggressive underground water on the metal constructions and beton. All sites in mining taps' limits around mining ventures with areal of groundwater's salinization are not suitable for construction through high intensification of geodynamic processes, existence of ecological planning restrictions and explosive tectonic disturbances.										

Fig. 3 Estimated natural and technogenic factors for construction assessment of Kalush city (fragment)

1) Suitable for construction (32% of area): local sites of III, IV, V, VII districts without any processes;

2) Little use for construction use (24% of area): local sites of III, IV, V, VI, VII, VIII districts with manifestation of aquifers' salinization, corrosive aggressiveness of groundwater on metal elements, inundation and waterlogging, explosive tectonic disturbances, buffer zones of ventures' mining taps;

3) Useless for constructions (34% of area): local sites of III, IV, V, VII districts, which situated inside of ventures' mining taps with groundwater's corrosive effect, tectonic disturbances and I, II, IX districts completely;

4) Useless for constructions, which require primary reclamation (10% of area): districts from X to XXIII. They are characterized by combination all dangerous processes and existence of ecological and engineering restrictions.

The proposed method of assessment engineering geological zoning allows to provide credible and accurate information for the construction development direction's understanding and operational ecological decision making.

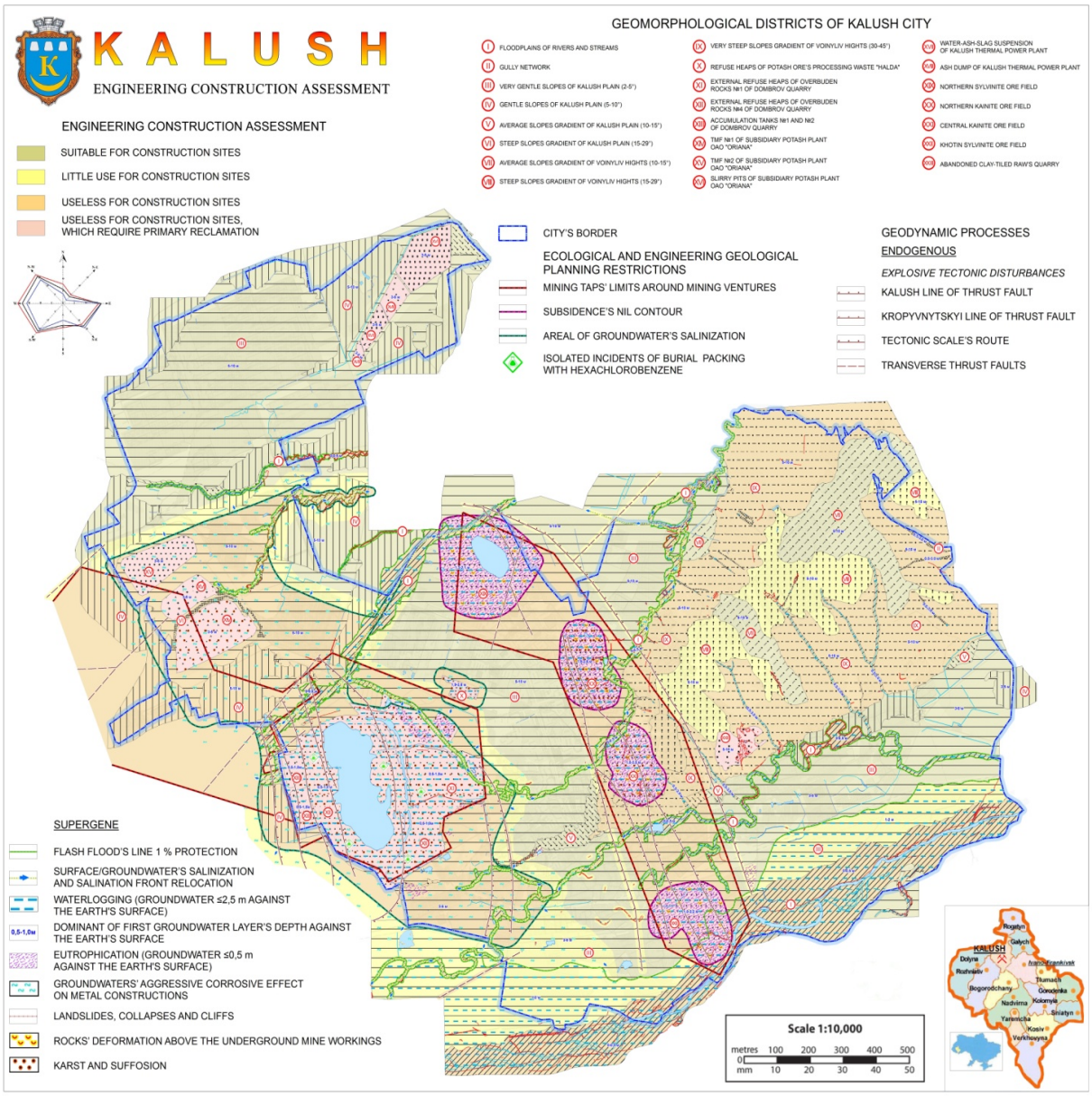

Fig. 4 Engineering construction assessment of Kalush city

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Research of heat exchange and hydrodynamic characteristic of unified package of cold layer of RAH

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Abstract – The research of heat transfer processes and hydraulic resistance of unified package of cold layer of RAH is depicted at this work. The graphic dependence of the change in the coefficient of hydraulic resistance and Nu number for unified packages with single line of sheets and simplified profile with corrosion resistance enamel from the Reynolds number for different values of the length of the replaced areas was constructed.

Keywords – boiler, regenerative rotary air heater (RAH), the packing of cold layer and hydraulic resistance.

Introduction

The elaboration of modern suited heat exchanged installation to allow for peculiarity their assembling and design, irregularity of distribution of thermal and hydraulic parameters, also increase of effectivity their work impossible without solution of topical problems such as intensification of heat transfer. With adding to power of thermal generation equipment, markedly weight and size dimensions of heat exchanges are growing. The our purpose to carry out a decrease of volume and mass maintaining stable temperature level of equipment account of intensification of heat transfer processes have to be important and to provide significant part of metal safe at production of convection heating surface of heat exchange unit heating. The research of processes of hydrodynamic at the essential constructions of convective regenerative rotary air heater are necessary for improvement these constructions [1].

Corrugated sheets of cold layer of packing regenerative rotary air heater are made of

- a protective layer (elimination). It has a sheet the Ст 08 КП and double-side covering with protective acid-resistant enamelled layer at the core.

- without protective layer. It can be either steel with mark 10ХСНД or steel 08пс with thickness 1 - 1.2 mm.

As is known from [1]: for sake of maintance of long exploitation heat exchange surface in condition aggressive sulfate medium exhaust gases of boiler the heating packing of package cold layer, which are located in zone with the most corrosive wear, it is covered by double layer surface with acid-stable enamel mark A - 20 (ECK - 20).The thickness enameling surface consists of 0,16 – 0,35 mm in each side.

The research has born out the high efficiency of usage enamel packing of layer regenerative rotary air heater at boilers, which are worked even by high sulphur content fuel. Enamel packing of cold layer exaggerates packing from steel marks 10ХСНД and 10ХНДП approximately multiply by 1.5 - 3 times and it is a less sensible to temperature condition and pollution intensity. As is known from [1, 3, 6]: during the burning the sulfur fuel oil the corrosive resistance of enamel packing is more than fivefold concerning the usual packing of cold layer of regenerative rotary air heater. Due to the reduction of the surface roughness in the coating enamel sheets, the heat transfer coefficient is increased by 5%, and the aerodynamics resistance do fenamelled packing is reduced by 10 % compared with the metal gasket and, moreover, facilitates the cleaning surface of the ash deposits.

For simplification of technology of manufacture bundle of packing [2] and for change of intensified packing that have reached the end of their operational lifetime, the unified packing was designed. It consists of monoprofile sheets with different steps among straight corrugations (Fig 1, a) Equivalent diameter of packing is 9.8 mm.

In the cold part of the RAH-88 of the boiler TGMP-314 [2], at the beginning of operation, a packing of a simplified profile of smooth and spacer sheets with long corrugations without slope was installed (Fig. 1, b)

The unified package simplified profile set at cold part of RAH in recent years (Fig 1, c). For protecting against low temperature corrosion the package sheets are covered by corrosive emal. For decrease the intensity of pollution in channel the equivalent diameter of package add to 11.5 mm

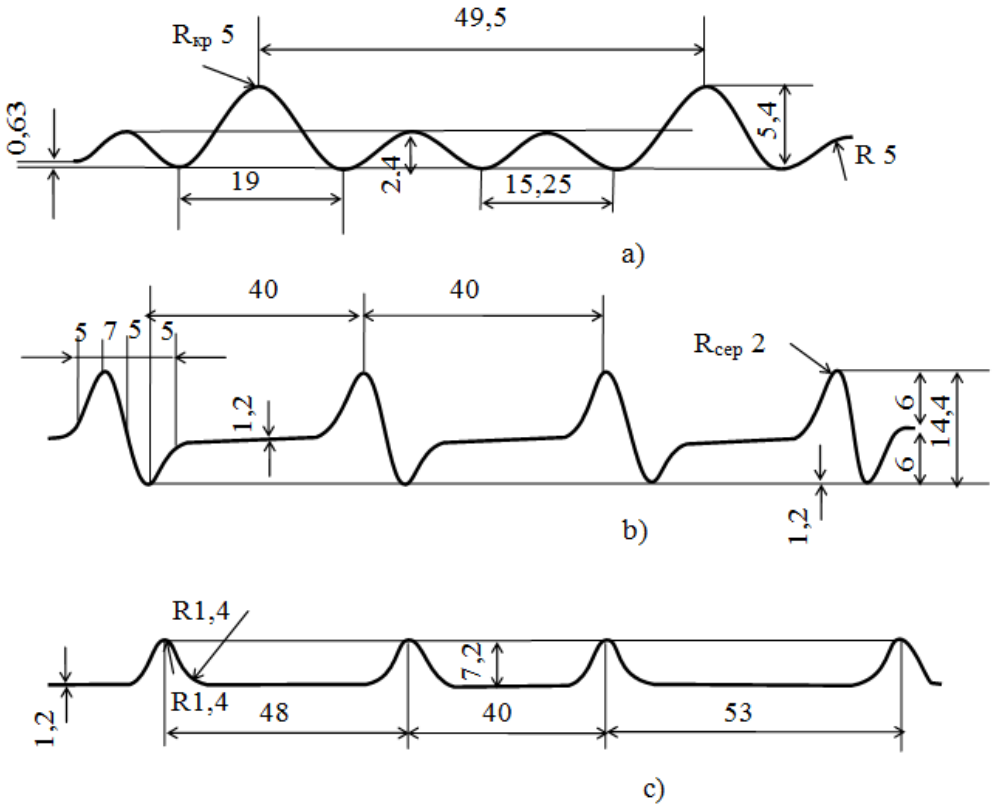

Fig 1. Profile sheets of RAH cold package

There is an analytical decision of the problem about uneven distribution of gases temperature after regenerative rotary air heater at this task [4]. It is shown considerable temperature gradient takes place in the intersection. However, the solution has done of heat transfer coefficient through movement of stuffing at the canal during the turbulent flows without reckon in available enamel surface at this work.

Depending on the work [5, 7] presented Nu criterion and coefficient of friction from Reynolds number for construction of package, which are made from steel sheets. However, all calculation are fulfilled without taking into consideration availability enamel surface.

The research of coefficient of Hydraulic resistance for padding with triangular channels of hot and cold layer of RAH has depicted at this work [8]. The graphic dependence is built of alteration of hydraulic resistance for padding with triangular channels from Reynolds number because of different meaning of the length of offset position. Although, packages of cold layer of RAH are researched, however triangular channels of bundle are constructive featured from researching profile.

Presenting main materials

The research of heat transfer processes and hydraulic resistance in direct channels of clear enamel packing of cold bundle packing layer of RAH packing are performed for formulas for smooth tube with changing because of influence of technical smoothness by rate coefficient C_f.

For enamel packing heat transfer is calculated by the formula:

$$\frac{Nu}{Nu_0} = 0{,}9 \qquad (1)$$

$Nu_0 = 0{,}023 \cdot \mathrm{Re}^{0,8} \cdot \mathrm{Pr}^{0,4} \cdot C_e \cdot C_\phi$ - Nu number for smooth channel. C_e – correction of the relative length of channel; C_ϕ – temperature correction factor; It is determined for nomogram 1 fig. 8.6. [2].

In order to determine Nu criterion for unified packages of cold bundle RAH from the air and flue gases was chosen changes in the speed range $7 < \omega < 30$ m/sec.

The results are shown on fig 2. There mal conductivity, body and value of Pr criterion for the air and flue gases are determined for average temperature of coolant.

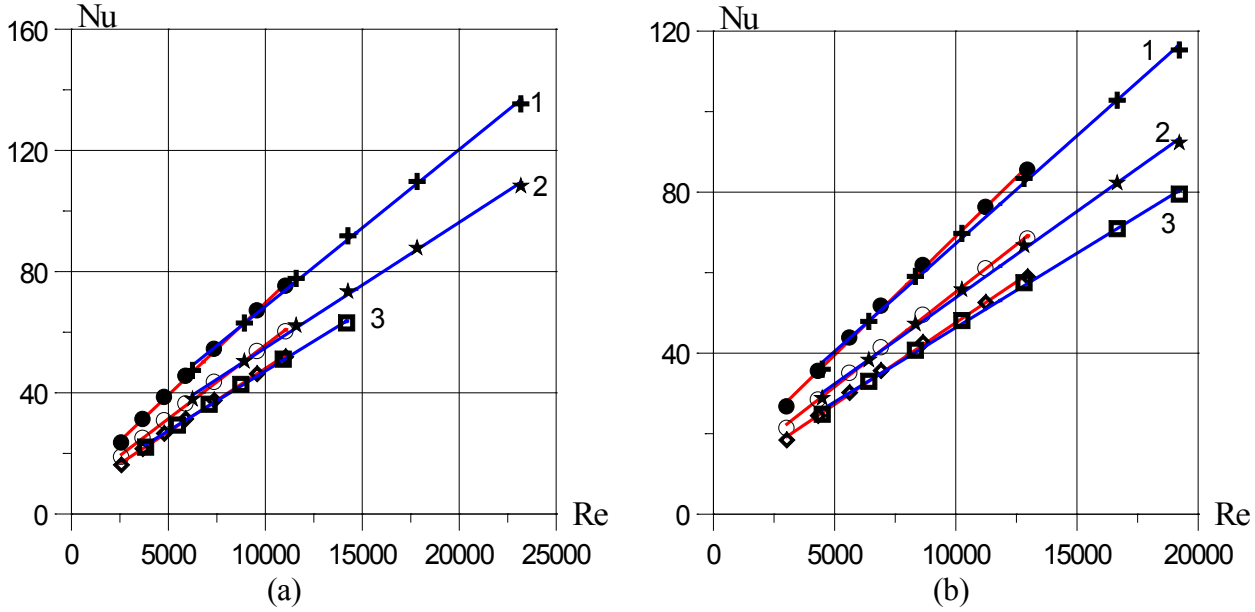

Fig 2. Dependence Nu criterion from Reynolds criterion for unified package of the cold bundle:

a) Monoprofile sheets (Fig 1, a) with $d_e = 9{,}8$ mm;

b) Simplified profile with rust resistant enamel (Fig 1, c) with $d_e = 11{,}5$ mm

In circumstances:1 – L = 30 mm; 2 – L = 70 mm; 3 – L = 110 mm;

Red line – flue gases with average temperature 418 K;

Blue line – the air with average temperature 323 K

As we can see from fig 2 the intension of heat transfer at unified package of simplified profile with rust resistance enamel from flue gases is more than unified package by 1.4 with single profile sheets for all research of tested length values of offset portion L. However, from side of air the intension of heat transfer unified package of simplified profile is less than unified package of single profile sheets by 0.76 at tested compass of change L. The increase equivalent diameter of package by 1.17 can be resulting in reduce intension contamination of channels and meantime alternation of heat loss coefficient from air and gases side that can be vindicated.

The hydraulic resistance of enamel package of cold bundle of RAH can be calculated by the formula

$$\lambda = \frac{0{,}303}{(\lg \mathrm{Re} - 0{,}9)^2} \cdot C_l \qquad (2)$$

C_l - determined for nomogram on fig 8.6. [2].

For compass Reynolds number meaning 3 000 < Re < 10 000 in different meaning length of offset portion L are constructed (Fig 3) by the Eq. (2):

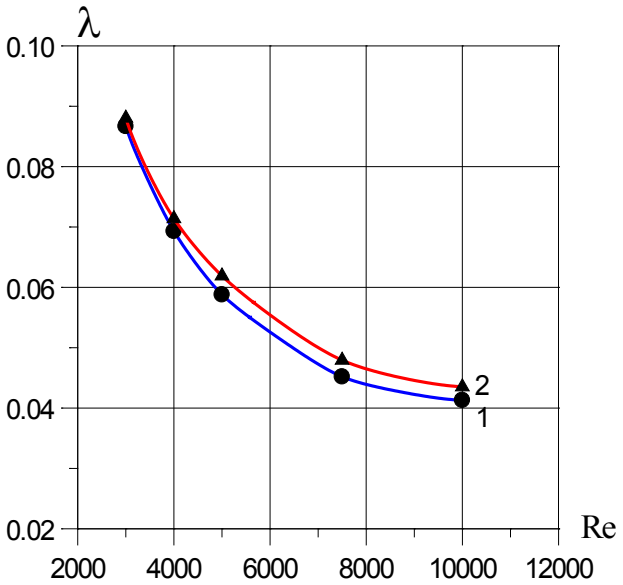

Fig 3. Dependence coefficient resistance of package from Reynolds number in different meaning length of offset portion 30 < L < 110 mm for unified package cold bundle of RAH:
1. Monoprofile sheets (Fig 1, a) with d_e = 9,8 mm;
2. Simplified profile with rust resistant enamel (Fig 1, c) with d_e = 11,5 mm

As we see on fig. 2, in the area close to the turbulent regime (Re ≈ 10^4), the meaning coefficient resistance of package (Fig 1, c) is more than for unified package with monoprofile sheets by 1.05 (Fig 1, a).The change coefficient resistance of tested package in an area close to the laminar regime (Re ≈ 3000) has a similar character, however, the value of the resistance coefficient λ is 1.016 times more. The increase coefficient resistance is not considerable and it did not significantly affect to operational parameter of packages.

Conclusion

For sake of research of heat exchange and hydraulic parameters of cold layer of RAH has been used unified package with monoprofile sheets and simplified profile with rust resistance enamel. The enamel package of bundle of cold layer in resilience doesn`t exceed package from steel approximately by 1.5 - 3 times and is less sensible to temperature regime and intension contamination.

Fundamental parameters that affect the thermal and technical parameters of package are the geometric dimensions of the waves and also equivalent diameter. The unified package of simplified types has extended by 1.17 times equivalent diameter and characterized good operational parameter and takes account danger of contamination of surface heating by means of enamel surface. From side of fuesgases for an area close to the turbulent regime, the increase length offset portion L by 3.67 times nose results to increase heat intensity by 1.14 times has been determined. At that same an area of meaning coefficient of resistance for package

simplified profile rust resistance enamel is more than unified package by 1.5 with monoprofile sheets.

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Energy-Shaping Control of the Wind-Solar Power Plant with a Hybrid Energy Storage System

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Abstract - In this paper, the one of variants of construction of a wind-solar power installation with a hybrid energy storage system (HESS) is presented. Energy-shaping control systems with and without injection of additional interconnections and damping are synthesized for such object. A computer comparative study of the efficiency of the obtained systems was conducted.

Keywords - *wind-solar power installation, control system, energy-shaping control, hybrid energy storage system.*

Introduction

The modern development of scientific and technological progress puts the task of finding efficient energy sources to meet the needs of humankind, taking into account the environmental friendliness of their use [8]. Among the green energy sources, also called alternative energy sources or renewable energy sources, the most popular are solar energy, the source of which is solar radiation, and wind, the source of which is wind power [13].

However, one of the major disadvantages of both solar and wind power plants is that the generation of electricity from these sources is not permanent. This aspect determines the feasibility of using solar and wind power plants together, increasing the chances that the energy received from the collaboration of these sources will be sufficient to meet the needs of the consumer.

At the same time, the use of such a wind-solar power plant creates the need for proper, effective control of this system, which is the relevance of this scientific work.

Energy-shaping control

One of the important trends in modern theory of automatic control is the physical theory of automatic control, based on physical laws, and based on these principles the system of energy-shaping control is designed [9]. The basis of such control is the equation of the total energy function (Hamiltonian), which has the form [2]:

$$H(\mathbf{x}) = \frac{1}{2}\mathbf{x}^{\mathrm{T}}\mathbf{D}\,\mathbf{x} \quad (1)$$

where $H(\mathbf{x})$ is the total energy function, x is the state vector, $\mathbf{D}$ is the diagonal matrix of the inertia coefficients of the system.

The purpose of the energy-shaping control is to ensure that the system operates at the desired equilibrium point x_0, which is defined by the task signal. This is achieved according to the equation [7]:

$$H_d(\mathbf{x}) = H(\mathbf{x}) + H_a(\mathbf{x}), \quad (2)$$

where $H_a(\mathbf{x})$ – control system energy correction function.

If we consider the system as a Hamiltonian with controlled ports (inputs and outputs), it will have the following form [12]:

$$\begin{cases} \dot{\mathbf{x}}(t) = \left[\mathbf{J}(\mathbf{x}) - \mathbf{R}(\mathbf{x})\right]\dfrac{\partial H}{\partial \mathbf{x}} + \mathbf{G}(\mathbf{x})\cdot\mathbf{u}(t) \\ \mathbf{y}(t) = \mathbf{G}^{\mathrm{T}}(\mathbf{x})\dfrac{\partial H}{\partial \mathbf{x}} \end{cases} \quad (2)$$

where **G(x)** – port matrix.

The process of synthesizing any ESCS starts when mathematical model of the controlled object, which is usually depicted by differential and algebraic equations, is reduced to the form (2), what means – to form vectors and matrices[13].

The next step is to equate the desired system with injected additional relationships and damping to the system equation according to the mathematical model of the object [4]:

$$\dot{\mathbf{x}}(t) = \left[\mathbf{J}(\mathbf{x}) - \mathbf{R}(\mathbf{x})\right]\frac{\partial H}{\partial \mathbf{x}} + \mathbf{G}(\mathbf{x})\cdot\mathbf{u}(t) = \left[\mathbf{J}_d(\mathbf{x}) - \mathbf{R}_d(\mathbf{x})\right]\mathbf{D}(\mathbf{x} - \mathbf{x}_0) \quad (3)$$

Synthesis of Energy-shaping control for the wind- solar power plant

Based on [1-6,10], we take the mathematical model of the wind-power plant with HESS in the following form:

$$\begin{cases} \dfrac{\mathrm{d}}{\mathrm{d}t} i_b = \dfrac{1}{L_b}\left[V_b - (1-\gamma_b)V_{dc}\right] \\ \dfrac{\mathrm{d}}{\mathrm{d}t} i_{sc} = \dfrac{1}{L_{sc}}\left[V_{sc} - (1-\gamma_{sc})V_{dc}\right] \\ \dfrac{\mathrm{d}}{\mathrm{d}t} v_{dc} = \dfrac{1}{C}\left[(1-\gamma_1)i_b + (1-\gamma_{sc})i_{sc} + (1-\gamma_w)i_w + (1-\gamma_{pv})i_{pv} - i_l\right] \\ \dfrac{\mathrm{d}}{\mathrm{d}t} v_{sc} = -\dfrac{1}{C_{sc}} i_{sc} \\ \dfrac{\mathrm{d}}{\mathrm{d}t} i_l = \dfrac{1}{L_l}\left(V_{dc} - E_l - R_l\, i_l\right) \\ \dfrac{\mathrm{d}}{\mathrm{d}t} i_{pv} = \dfrac{1}{L_{pv}}\left(V_{pv} - (1-\gamma_{pv})V_{dc}\right) \\ \dfrac{\mathrm{d}}{\mathrm{d}t} i_w = \dfrac{1}{L_w}\left(V_w - (1-\gamma_w)V_{dc}\right) \end{cases} \quad (4)$$

where L_b, L_{sc}, L_l, L_{pv}, L_w,– inductances in battery charge, supercapacitor, load, solar and wind circuits, respectively; R_l – active load resistance; E_l– load EMF; γ_b, γ_{sc}, γ_{pv}, γ_w – DC-DC impulse fill factors for the corresponding electrical circuits (similar to inductances); V_{dc} – voltage applied to the load.

Since the energy stores in such a system are inductors and capacitors, the vectors of state, input and output coordinates, as well as port matrix will be as follows:

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \end{bmatrix} = \begin{bmatrix} L_b i_b \\ L_{sc} i_{sc} \\ C\, v_{dc} \\ C_{sc} v_{sc} \\ L_l i_l \\ L_{pv} i_{pv} \\ L_w i_w \end{bmatrix} = \mathbf{D}\begin{bmatrix} i_b \\ i_{sc} \\ v_{dc} \\ v_{sc} \\ i_l \\ i_{pv} \\ i_w \end{bmatrix};\ u = \begin{bmatrix} V_b \\ 0 \\ 0 \\ 0 \\ -E_l \\ V_{pv} \\ V_w \end{bmatrix};\ y = \begin{bmatrix} i_b \\ i_{sc} \\ v_{dc} \\ v_{sc} \\ i_l \\ i_{pv} \\ i_w \end{bmatrix};\ \mathbf{G} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad (5)$$

where $x_1 \ldots x_7$ – elements of the state vector; $\boldsymbol{D} = diag\ [L_b\ L_{sc}\ C\ C_{sc}\ L_l\ L_{pv}\ L_w]$– diagonal matrix of inertias of the system.

Based on the selected vector of state x and according to (1), the Hamiltonian of the system takes the form:

$$H(\mathbf{x}) = \frac{1}{2}\mathbf{x}^{\mathrm{T}}\mathbf{D}\,\mathbf{x} = \frac{1}{2}\left(\frac{1}{L_b}x_1^2 + \frac{1}{L_{sc}}x_2^2 + \frac{1}{C}x_3^2 + \frac{1}{C_{sc}}x_4^2 + \frac{1}{l}x_5^2 + \frac{1}{L_{pv}}x_6^2 + \frac{1}{L_w}x_7^2 + \right) \qquad (6)$$

Then the matrix of interconnection of the mathematical model in the form of a port-controlled Hamiltonian system will be as follows:

$$\mathbf{J}(\mathbf{x}) = \begin{bmatrix} 0 & 0 & -(1-\gamma_b) & 0 & 0 & 0 & 0 \\ 0 & 0 & -(1-\gamma_{sc}) & 1 & 0 & 0 & 0 \\ (1-\gamma_b) & (1-\gamma_{sc}) & 0 & 0 & -1 & (1-\gamma_{pv}) & (1-\gamma_w) \\ 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -(1-\gamma_{pv}) & 0 & 0 & 0 & 0 \\ 0 & 0 & -(1-\gamma_w) & 0 & 0 & 0 & 0 \end{bmatrix} \qquad (7)$$

Damping matrix **R** will have only one not zero element – $r_{55} = R_l$.

Substituting the matrix into equation (3), we will synthesize the non-generating control system and obtain dependencies for the task signals. Synthesis was performed twice, for one system without the introduction of additional interconnections and damping (ESCS1), and for other with additional interconnections and damping (ESCS2).

Therefore, for ESCS1, the matrices $\boldsymbol{J}_a(\mathbf{x})$ and $\boldsymbol{R}_a(\mathbf{x})$ will be zero. Thus, we obtain the following laws for the formation of impulse fill factors for DC-DC converters:

$$\gamma_b = -\frac{V_b - V_{dc0}}{V_{dc0}};\ \gamma_{sc} = -\frac{V_{sc} - V_{dc0}}{V_{dc0}};\ \gamma_{pv} = -\frac{V_{pv} - V_{dc0}}{V_{dc0}};\ \gamma_w = -\frac{V_w - V_{dc0}}{V_{dc0}} \qquad (8)$$

For ESCS2 there was additionally interconnections by the coefficient J_{13} та J_{23} of the matrix $\boldsymbol{J}_a(\mathbf{x})$ and damping by the coefficient r_{22} of the matrix $\boldsymbol{R}_a(\mathbf{x})$, the following results were obtained, respectively:

$$\gamma_b = -\frac{V_b - V_{dc0} - V_{dc}J_{13} + V_{dc0}J_{13}}{V_{dc0}};\ \gamma_{sc} = -\frac{V_{sc} - V_{dc0} - V_{dc}J_{23} + V_{dc0}J_{23} + i_{sc}r_{22}}{V_{dc0}};$$
$$\gamma_{pv} = -\frac{V_{pv} - V_{dc0}}{V_{dc0}};\ \gamma_w = -\frac{V_w - V_{dc0}}{V_{dc0}} \qquad (9)$$

In order to investigate the efficiency of obtained systems, comparative studies were conducted. The computer model elements have the following parameters: $L_b = L_l = 0.001$ H, $L_{sc} = 0.0005$ H, $L_{pv} = L_w = 0.003$ H, $C = 0.01$ F, $C_{sc} = 45$ F, $U_{b0} = 24$ V, $U_{dc0} = 48$ V, $U_{sc0} = 30$ V. The system has three external perturbations: the voltage from the solar panel (Fig. 1), the voltage from the wind power plant (Fig. 2) and load EMF (Fig. 5). The task signals are designed so that the impact of each of them can be evaluated individually and in combination, which makes it possible to investigate the operation of the system and the processing of the task signals under different operation modes.

The following parameters were selected for the ESCS2:

J_{13} = 0.7 – it was investigated that this parameter influences the transient forcing, it is useful for maintaining the voltage V_{dc} at the desired level, and does not ensure the smooth flow of transients of the battery current.

J_{23} = 0.5 – according to studies, this parameter smooths out the transient of the current through the battery and forces the transient of the current through the supercapacitor.

r_{22} = 0.005 – the factor maintains the V_{dc} voltage at a given level and does not allow drawdown when the load is changed.

As can be seen from Fig.6 both systems ESCS1 (solid line) and ESCS2 (dotted line, Fig.3) provide the basic requirement - load voltage, namely, around 48V. Based on the obtained results, it can be said, that ESCS2 (dotted line, Fig.6) with the addition interconnections, better fulfills the task, both when changing the voltage from the power sources and when changing the load.

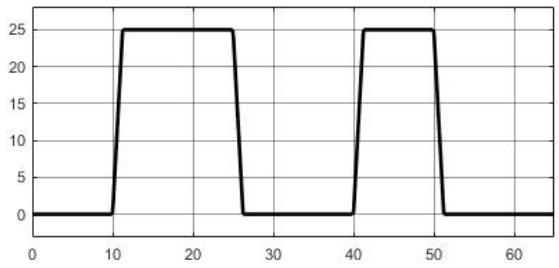

Fig. 1. Solar panel voltage

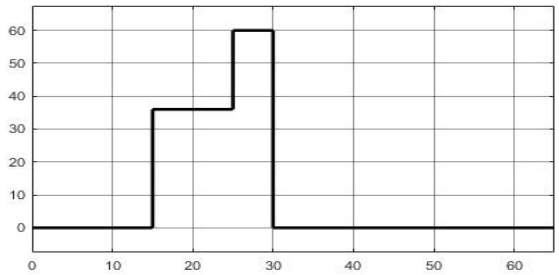

Fig. 2. Wind turbine voltage

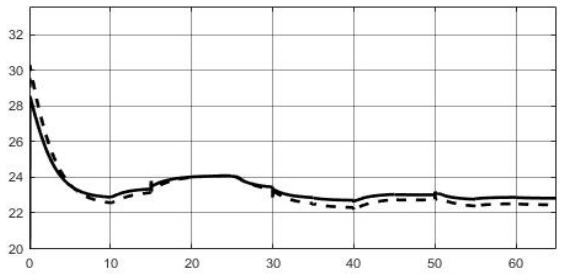

Fig. 3. Battery voltages

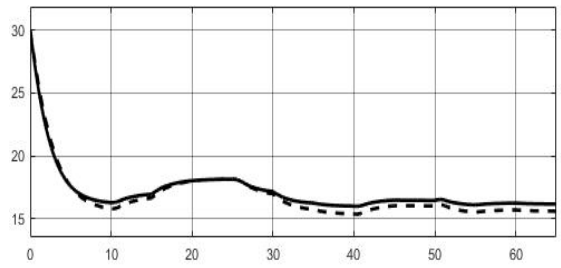

Fig. 4. Supercapacitor voltages

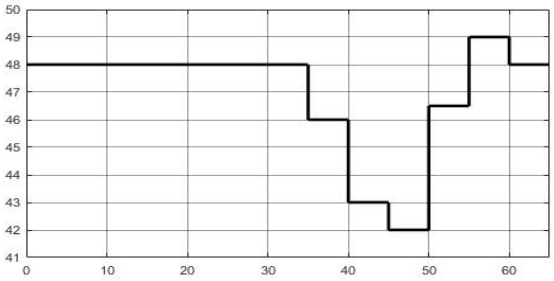

Fig. 5. Load EMF

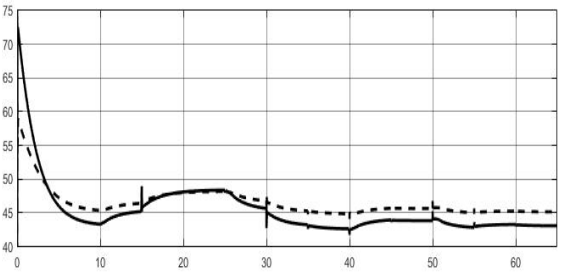

Fig. 6. Load voltage

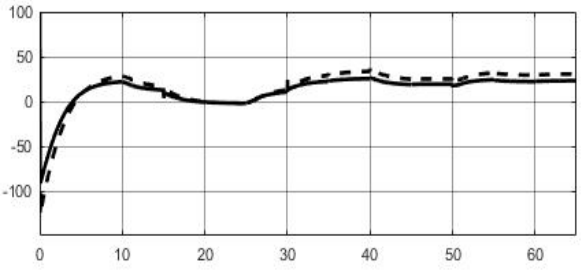

Fig. 7. Battery currents

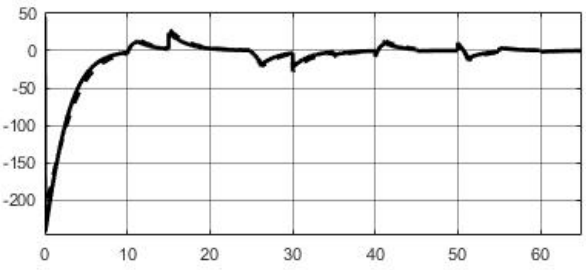

Fig. 8. Supercapacitor currents

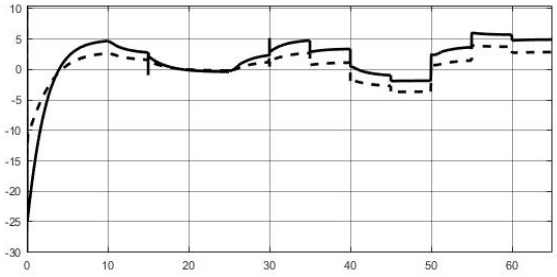

Fig. 9. Load currents

Conclusions

Using energy-based approaches, new ESCS have been obtained. Both ESCSs, with and without additional interconnections and damping, provide stable voltage on the load. The same applies to load current, the pulsations of which are slightly smaller over the entire operating range. The introduction of additional interconnections and dumping gives an opportunity to influence certain processes in the system. Despite a certain drawdown of the drive voltage when using System 2 with additional interconnections, the transients of the current through the battery are smooth and is maintaining at a certain level, which significantly increases the life of the batteries and makes it possible to reduce their required power.

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Limitation of internal overvoltages in power static converters with fully controlled thyristors

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Abstract – The methods of limiting internal overvoltages in power static converters with fully controlled thyristors used in power electronics are considered in the article. A matlab model of the surge arrester was created and a model of the converter into which the surge arrester was successfully implemented.

Keywords – smart grid, FACTS, limitation of internal overvoltages, power static converters, thyristors, surge arrester.

Introduction

In the Smart Grid concept, the problem of regulating the flow of electrical power is intended to be solved by means of power electronics and, above all, by converters based on fully controlled power thyristors and transistors [1].

Switching semiconductors causes complex transients in power static converters, which is accompanied by a redistribution of energy reserves in the RLC elements and, as a consequence, overvoltages may occur in them. The most characteristic cause of internal overvoltages is the mode of closing the control voltage of fully controlled semiconductor devices in the composition of converters for systems of flexible forwarding of alternating current (FACTS), compensation of reactive power or rectifiers of technological installations with improved coefficient of power, inductance, inductance, the period of closing time of the valves may be accompanied by repeated inductive emission of voltage:

$$L_{м}\frac{di_{м}}{dt}, \quad (1)$$

where $L_{м}$ is the inductance of the network.

Due to the high energy efficiency of using fully controlled thyristors in power converters for their operation in modes of forced thyristor closure at industrial frequency, the study of ways to limit switching surges is especially relevant.

Known methods for limiting overvoltages

The main ways to avoid the impact of this phenomenon on electrical equipment are:

1. Application of reverse diodes, which translate the current of the closing valve into a reverse diode, which is switched on with reverse polarity with respect to the main working semiconductor element; reverse diodes effectively prevent the occurrence of internal overvoltages in voltage converters made according to the schemes of autonomous voltage inverters.

2. Application of sniper (damping) units, in which the surge energy is stored in the form of a charge of the capacitor with its subsequent scattering in the resistor: RC - resistor-capacitor snapper, or RCD - resistor, capacitor, diode.

3. Application of surge arresters with nonlinear current rating:

a) varistors (nonlinear resistors) are not suitable to limit switching overvoltages due to their lack of speed.

b) suppressors (limiting diodes, power zener diodes) the most efficient and up-to-date way to limit internal overvoltages in valve converters.

The use of sniper units with capacitance of up to several microfarads and resistors of several tens of Ohms [5] to limit switching overvoltage through additional losses in sniper resistors is most effective for limiting switching overvoltages in low power converters.

As the main and universal method of limiting internal switching overvoltages for converters with fully controlled thyristors we suggest the use of limiting diodes. To prove their effectiveness, a number of models have been created in the visual programming environment of the Simulink Matlab software package.

The input data for estimating the multiplicity of surges in the mode of shutdown of a fully controlled thyristor are the temporal characteristics of the mode of switching off and the parameters of the network of connection to the power source. In fig.1 typical time characteristic are shown.

In modes with positive angle values, a rapid decrease in current due to the inductance of the power supply due to the closing of the thyristors with the control pulse can lead to the appearance of internal peak voltages on the elements of the conversion unit. The switching duration of the closing thyristor is mainly determined by the area of current drop to 10% of the closing current in the first phase of its shutdown (Fig.1). With this in mind, the rectifier valve should be selected from the condition that in the mode of generation of reactive shear power, the largest amount of voltage on them can reach the value

$$U_{v,max} \leq \sqrt{3}E_m + 2L_s\frac{0{,}9I_{d,nom}}{t_1} \qquad (2)$$

The traditional use of closing thyristors requires their opening and closing as soon as possible. Since the thyristors in the power rectifiers operate at the industrial frequency of the mains, the limitation du / dt can be achieved by applying a thyristor with a relatively slow closure, ie by increasing the value of time. Protective R-C diode links or semiconductor surge suppressors may be used to limit peak surges.

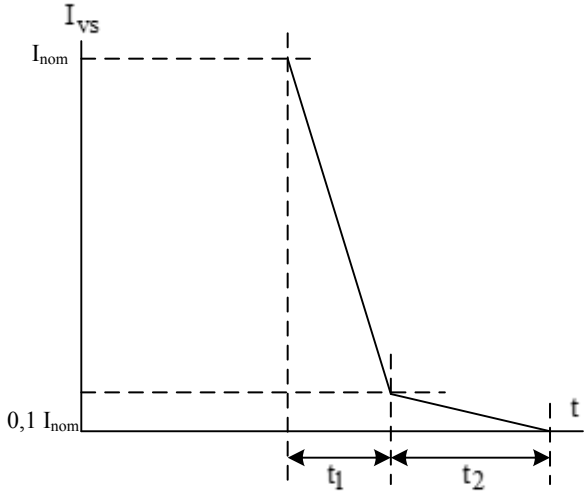

Fig.1 - Timing diagram of the mode of switching of the two-operative thyristor: t_1 - duration of the main phase of switch-off; t_2 - the duration of the final phase

Limiting diodes

Among all methods, the most effective use of TRANSIL or TVS diodes.

TVS diodes were created in 1968 in the United States to protect industrial equipment from discharges of atmospheric electricity. In the conditions of use of electronic devices both industrial and household purpose it is of great importance to protect these devices from natural electrical impulses.

In the sixties, the first production of diodes specially designed for surge suppression was organized at the Irish GSI plant. Soon, such diodes were launched by SGS-Thomson under the brand name TRANSIL and TRISL. Currently, the electrical engineering giant GENERAL INSTRUMENTS (GI) is manufacturing GSI diodes. According to some reports, the daily performance is 1.5 million devices, with about half of the protective diodes having a classic design, the other half being manufactured in surface mount housing (SMD). Protective diodes manufactured by GI are designated TVS - Transient Voltage Supressor. TVS and TRANSIL are different commercial names for the same diodes. The designations of both products are the same for many classes of diodes.

The diodes are manufactured in both unidirectional and bidirectional designs. Unidirectional execution is used to limit overvoltages to only one polarity, so TRANSIL devices of this type must be switched on to the polarity-adjusted circuit. TRANSIL bi-directional diodes are designed to limit the overvoltage of both polarities. The TRANSIL bi-directional diode can be assembled from two unidirectional TRANSIL diodes by counter-rotating them.

Unlike varistors, which are also used to limit surges, TRANSIL diodes are more fast-acting. The TRANSIL diode has a response time of several picoseconds. TRANSIL bi-directional diodes always switch on in parallel with the equipment.

Typical value of varistor actuation time when exposed to overvoltage is 25 ns. This may not be sufficient for some equipment. The theoretical pulse rate of the TRANSIL diodes per pulse is in the picosecond region. The manufacturer states that in the laboratory it is difficult to create a transient pulse, which the TRANSIL diode would operate with a delay, that is, at its peak. The simulated rise time of the front was always within 5 ns - in practice, this time could be several picoseconds.

TRANSIL diodes are specially designed for surge suppression in emerging transients. The main field of application is overvoltage protection of electronic equipment of cars, circuits of telecommunications and data transmission, protection of powerful transistors and thyristors.

Basic parameters of TRANSIL diodes:

V_{rm} - Peak Reverse Voltage - the maximum operating voltage at which current passing for a long time does not cause the element to go out of work.

V_{br} - Break-down Voltage - voltage at which there is a sharp increase in the flow of current, and the rate of increase of current is much higher than the rate of increase of voltage.

V_{cl} - Clamping Voltage - the maximum voltage for the so-called "normalized" maximum peak current pulse Ipp.

I_{pp} - Peak Puls Current - Peak current in operating mode

V_f- Forward Voltage

I_f - Forward Current.

Since there are currently TRANSIL diodes in the MatLab software library that can simulate the proposed capacitor battery, I have developed a dynamic model of an TVS diode that can be adjusted according to user needs.

Creation of mathematical model of TRANSIL diode in MatLab Simulink environment

The electrical blocks presented in the SimPowerSystem library are generally unavailable for viewing and editing their contents. However, sometimes the user has to get acquainted with

the model device at least in order to better understand how it works. Often the user is not completely comfortable with the library block, and he would like to make minor changes to best suit his or her task. It is also very useful to get acquainted with the unit of the main units in order to learn how to do them yourself. For the implementation of the above tasks, SPS has a separate library of Simulink models of electrical units (Simulink prototypes).

The user can open the library from the main MATLAB window by typing in the powerlib_models command line.

The SimPowerSystems block library is quite extensive, however, sometimes the user-required device model may be missing. This applies, for example, to non-linear resistors, saturated reactors, new types of electric motors, etc. In this case, the user can create the model himself based on the Simulink blocks and the SPS blocks. The general structure of the model is shown in Fig. . In the circuit, a voltage meter is connected in parallel to the controlled current source. Between the output of the voltage meter and the input of the current source is included Simulink model, which realizes the desired voltage-current characteristic of the device. A resistor is also connected in parallel to the source. Its presence is due to the fact that a large number of SPS units are made on the basis of current sources. When connecting such blocks in series, the current sources are turned on in series, which is unacceptable.

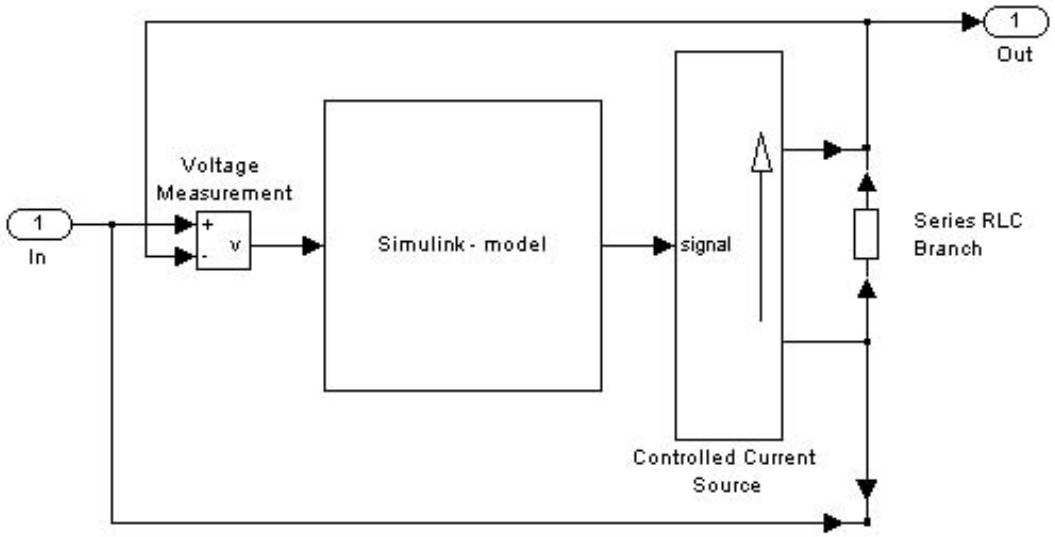

Fig.2. Structure of the custom model of the Simulink unit

The presence of a decoupling resistor allows you to include such blocks in series. The resistance value of the resistor should be chosen sufficiently large to have a minimal effect on the characteristics of the block being created (usually its value for power electrical units is selected within 500 - 1000 Ohms). The terminals of the block are the input and output ports. Thus, to create an electrical block, the user must first create a simple Simulink model, the input of which is a signal proportional to the voltage at the clamps of the device, and the output is a signal proportional to the current of the device, and then use this model in the diagram shown in Fig. . When creating multiphase devices, it is usually necessary to create models of individual phases, and then turn them on as desired.

The current-voltage characteristic of the diode is given by the formula:

$$i = I_0 \left(\frac{u}{U_0} \right)^{\alpha} \qquad (3)$$

where i, u - instantaneous values of current and voltage;

U_0 is the voltage threshold;

I_0 is the value of the current of the device at the threshold voltage;

α - the degree of determining the nonlinearity of the device is usually in the range from 0 to 50.

On the basis of the current-voltage characteristic (3) we have created a custom electrical block with parameters repeats the parameters of the power supply system of the enterprise, in the Simulink environment, the block diagram is shown in Fig.3.

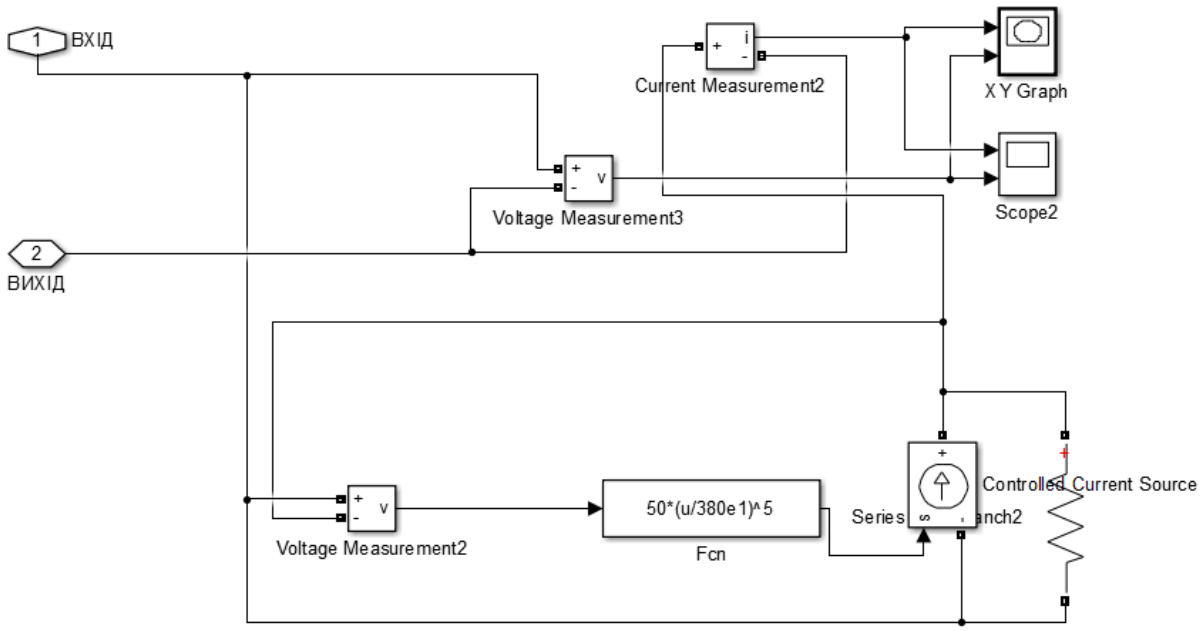

Fig.3. Model of electrical unit that replicates the parameters of the TVS diode

For ease of use, the connecting unit into an electrical element is shown in Fig.4.

Fig.4. Output block

Modeling of the selected model of the reactive power compensation system and implementation of the created surge arrester

To limit the switching voltages, I apply the previously created block of the surge suppressor, which simulates the parameters of the TVS diode, we connected Figure 8.12 - Schematic diagram for simulating the operation of a single-phase bridge converter in the mode of generating reactive power compensation with the implemented TRANSIL diode unit. it in parallel to the model of the capacitor battery. The obtained scheme is shown in Fig.5.

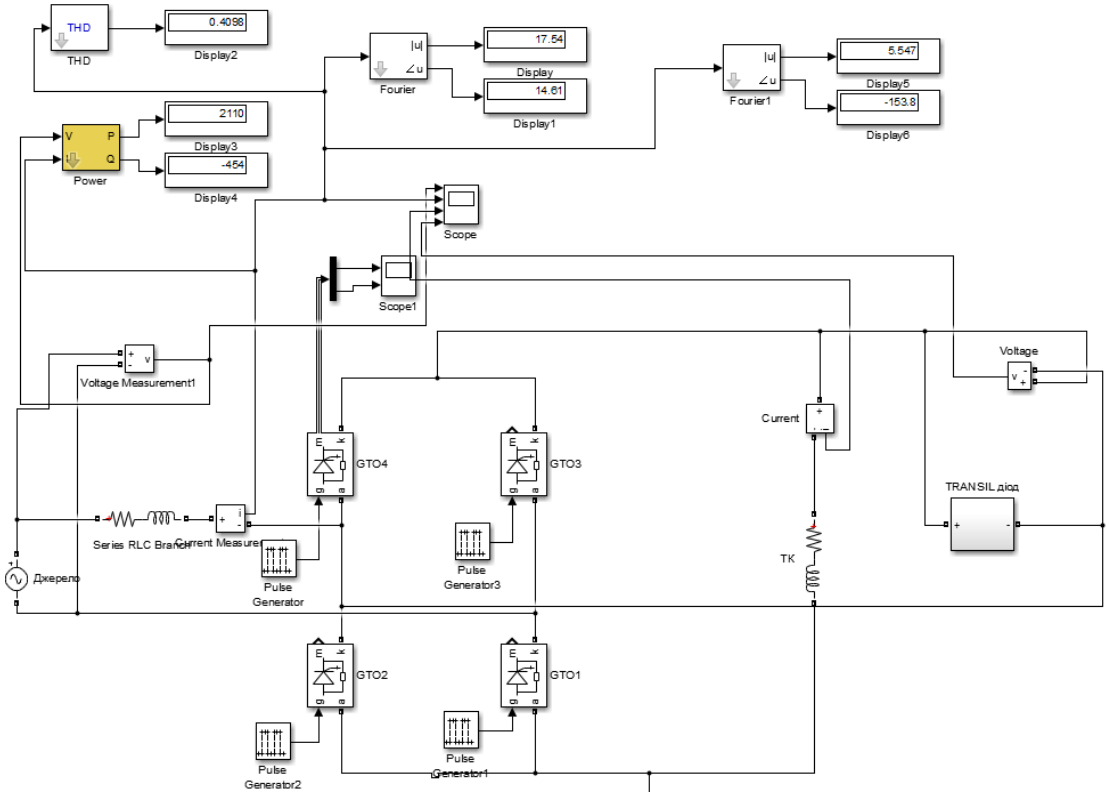

Fig.5. Schematic diagram for simulating the operation of a single-phase bridge converter in the mode of generating reactive power compensation with the implemented TRANSIL diode unit.

After the simulation of this scheme was obtained graphs of voltage. (Fig.6).

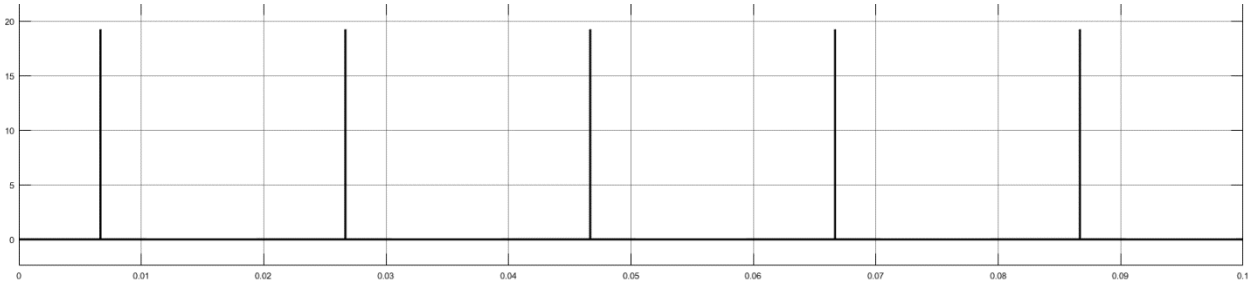

Fig.6. Graph of voltage versus simulation time without diode unit

As we can see, from fig. the switching overvoltages in the system go beyond what is inadmissible to the converter system, since such overvoltages are capable of damaging the equipment.

After the simulation of the model in which the TRANSIL diode unit was implemented, the graphs of current voltage (Fig.7) were obtained.

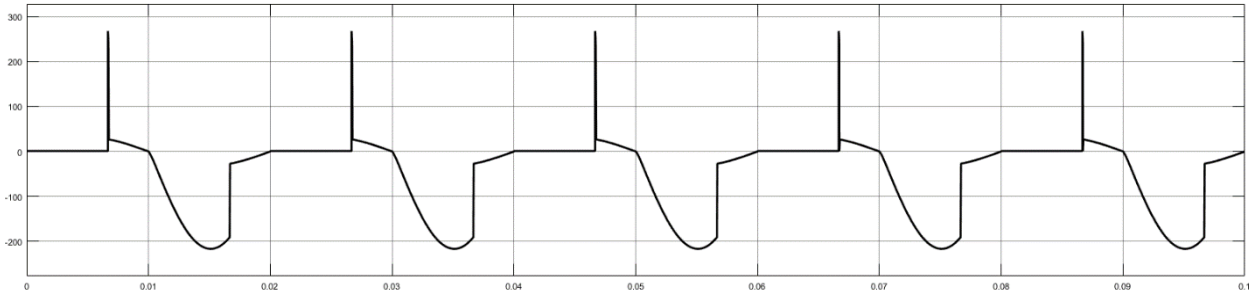

Fig.7. Graph of voltage versus simulation time without diode unit with a TVS unit implemented.

Conclusion

In the article main causes of internal surges in power static static converters with fully controlled thyristors is considered. Various variants of limiting the above-mentioned voltages were also considered. The main part of the work was to create a Simulink model TRANSIL diode and implement it in the model of the converter. The obtained simulation results prove the effectiveness of the created model.

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Access to the EU public procurement market in the context of the EU-Ukraine Association Agreement

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Abstract - the present paper is dedicated to the problems of gaining access to the EU public procurement market in the context of the EU-Ukraine Association Agreement. Special consideration is given to the role of the WTO Government Procurement Agreement in ensuring the reciprocal access to public procurement markets of Ukraine and the EU. The author comes to the conclusion that despite the fact that market access within the EU-Ukraine Association Agreement is linked to the progress of legislative approximation, Ukraine has already gained an access to the EU public procurement market on the principles of non-discrimination and national treatment according to the WTO Government Procurement Agreement. However, the paper shows some limitations in the EU coverage schedule within the framework of the WTO Government Procurement Agreement, which shrink the opportunities for Ukrainian suppliers in comparison to the Association Agreement with the EU.

Keywords – public procurement, market access, EU-Ukraine Association Agreement, WTO Government Procurement Agreement, contracting authority, legislative approximation.

Introduction

Chapter 8 of Section IV and Appendix XXI of the European Union (EU)-Ukraine Association Agreement [1] address the relationships in the public procurement field, providing for the public procurement market liberalisation and for the national legislation harmonisation with the requirements of the EU Treaty and the detailed provisions of the EU Directives on public procurement. The inclusion of public procurements to the process of European integration is stipulated by the fact that they constitute a significant sector of the economy. Estimates show that the public procurement in Ukraine constitutes approximately 13% of GDP [2]. In its turn, the EU is a one of the largest public procurement markets in the world. Every year over 250 000 public authorities in the EU spend around 14% of GDP on the purchase of services, works and supplies [3]. These data prove that the EU and Ukrainian market is mutually attractive for potential suppliers. However, according to the EU-Ukraine Association Agreement the market access is linked to the progress in the process of legislative approximation. The present research gives an appraisal of Ukraine's opportunities to take part in the EU public procurement market in the context of the EU-Ukraine Association Agreement.

The EU-Ukraine Association Agreement: market access obligations

According to Art. 154 of the EU-Ukraine Association Agreement the Parties have agreed that the effective and reciprocal opening of their respective markets should be carried out gradually and simultaneously. During the process of legal approximation, the level of market access provided by the Parties on a reciprocal basis is associated with the progress made in adapting the legislation in accordance with Annex XXI-A to this Agreement. The decision to start the next phase of market opening is based on an assessment of the quality of the adopted legislation, as well as its practical implementation. Such assessment is regularly carried out by the Trade Committee. To the extent that a Party, according to Annex XXI-A to the EU-Ukraine Association Agreement, has opened its procurement market to the other Party, the EU Party will grant access to contract award procedures to Ukrainian companies - whether established or not in the EU Party - in accordance with the EU public procurement rules under treatment no less favourable than that accorded to EU Party companies; Ukraine will provide access to contract

award procedures for EU Party companies - whether established or not in Ukraine, in accordance with national procurement rules under treatment no less favourable than that accorded to Ukrainian companies [1]. According to the Annex XXI to the EU-Ukraine Association Agreement an indicative time schedule for institutional reform, legislative approximation and market access is established. It comprises 5 phases, the last of which should be implemented within 8 years after the entry into force of the Agreement. That is, providing full access to the EU procurement market in accordance with the EU rules is linked to the implementation of the last phase of legislative approximation. The aforementioned phases correspond to the stages of the 'roadmap' (Strategy for the reform of the public procurement system), which was developed and approved by the Cabinet of Ministers of Ukraine in order to fulfill the requirements of the Association Agreement with the EU.

Based on the latest Decision of the EU-Ukraine Association Committee in Trade Configuration of 14 May 2018 [4], there is a positive Committee's opinion only concerning Ukrainian 'roadmap' on the implementation of legislation in the field of public procurement. However, with regard to the successful implementation of the first phase of legislative approximation and gaining access to the relevant part of the EU procurement market there is no solution in the Decision.

Does it mean that Ukrainian economic operators currently do not have access to contract award procedures pursuant to EU public procurement rules under treatment no less favourable than that accorded to EU Party companies, unless each phase of market opening is finished and there is a Trade Committee decision on proceeding to a further phase?

The Legislative Framework of the Ukrainian Procurement Regime: market access for the EU economic operators

It should be noted that Ukraine has already granted access to its public procurement market for foreign economic operators, including the European suppliers. The Law of Ukraine "On Public Procurement", which was adopted in 2016, establishes one of the main principles of procurement - non-discrimination of participants. According to Art. 5 of this Law domestic and foreign participants of all forms of ownership and organizational and legal forms participate in procurement procedures on equal terms. The previous Law of Ukraine "On Government Procurement" of 2014, which expired, provided for a similar norm. In addition, according to Art. 10 of the Law of Ukraine "On Public Procurement" notices of intended procurement must be additionally published in English if the expected purchase value exceeds the equivalent for goods and services – EUR 133 thousand, for works – EUR 5150 thousand, which corresponds to the thresholds previously set out in Appendix XXI-P of the EU-Ukraine Association Agreement. Furthermore, there is a longer period for submitting tenders for such kind of procurement. The contracting authorities publish the notices of intended procurement and tender documentation no later than 30 days prior to the day of the tenders disclosure. For purchases that do not exceed the specified thresholds, this period is 15 days. This is due to the need to provide sufficient time for foreign suppliers to prepare and submit request for participation.

Thus, the unrestricted access to Ukraine's procurement market has been existing since the start of the Association Agreement with the EU. Indeed, harmonized rules on procurement procedures play an important role in accessing markets, when economic operators understand the process of participation on both sides, however, Ukraine has no right to grant access to economic entities from the EU under treatment less favourable than that accorded to Ukrainian companies.

The WTO Government Procurement Agreement: obligations for the EU and Ukraine on market access

In May 2016, Ukraine became a full member of the World Trade Organization Agreement on Government Procurement (GPA), the main objective of which is the opening of procurement markets for the parties to this Agreement on the basis of the principles of non-discrimination and national treatment. The aggregate size of market access commitments under the GPA has been valued at US $1.7 trillion [5]. The GPA is a plurilateral agreement, which means that it is binding only on those WTO members that have decided to join it. At present, the GPA has 20 parties (the EU as a one party) comprising 48 WTO members [6]. The GPA does not cover all procurement of its members, but only those that are defined by the parties in their coverage schedules, which contain seven annexes and formed during the negotiations of the existing members of the GPA with the acceding countries. Ukraine and the EU are the members of the GPA, thus they are obliged to provide mutual access to the procurement markets, regardless of the degree of adaptation of Ukrainian legislation to the requirements of the EU, however, taking into account the scope defined in the coverage schedules. In this context and potential participation of Ukrainian economic operators in EU procurement, it should be analysed how far the EU public procurement market in terms of the GPA differs from the EU market within the framework of the Association Agreement.

Based on the fact that aforementioned Agreements apply to procurement of minimum estimated value equal to or exceeding certain specified financial value thresholds, it is important to analyse thresholds indicated in these Agreements. According to the latest Decision of the EU-Ukraine Association Committee in Trade Configuration of 14 May 2018, Annexes XXI to Chapter 8 "Public Procurement" were updated taking into account new EU Directives on public procurement. The following tables provide data based on updated thresholds.

Table 1

Thresholds in Annex 1 – central government entities [7]

GPA	EU-Ukraine Association Agreement
Goods	
144 000 EUR	135 000 EUR
Services	
144 000 EUR	135 000 EUR
Construction services and work concessions	
5 548 000 EUR	5 225 000 EUR

Table 2

Thresholds in Annex 2 – sub-central government entities

GPA	EU-Ukraine Association Agreement
Goods	
221 000 EUR	209 000 EUR
Services	
221 000 EUR	209 000 EUR
Construction services and work concessions	
5 548 000 EUR	5 225 000 EUR

Table 3

Thresholds in Annex 3 – other entities (contracting entities in the utilities sector)

GPA	EU-Ukraine Association Agreement
Goods	
443 000 EUR	418 000 EUR
Services	
443 000 EUR	418 000 EUR
Construction services and work concessions	
5 548 000 EUR	5 225 000 EUR

With regard to the analysis of the thresholds within the GPA and the EU-Ukraine Association Agreement, the difference between them is insignificant. However, in Annex 7 of the EU coverage schedule, where the GPA parties indicate procurement that is not covered by the Agreement, the EU has indicated its exemptions. For example, GPA does not cover EU procurement of agricultural products made in furtherance of agricultural support programmes and human feeding programmes. In addition, there are certain limitations in the approach chosen by the EU to determine its coverage scope. Within the framework of the GPA, for the goods and services the EU has chosen a "positive list" approach, which covers only those goods and services that are individually listed in the Annexes. At the same time, there are countries, such as Ukraine, which have chosen a "negative list" approach, where the items that are covered by the GPA are the ones not included in the list specified. As a rule, the negative list opens more goods and services, since it includes new products and services that are developed. Furthermore, there are some limitations in coverage of contracting authorities. For example, Annex 1 of the EU coverage schedule states that for the goods, services and suppliers of Liechtenstein, Switzerland, Iceland, Norway, the Netherlands with respect to Aruba, the GPA covers procurement *by all* central government contracting authorities of EU member states [7]. The list of central government contracting authorities of EU member states that is specified in the Annex 1 for the mentioned countries is indicative, to be more specific this list is illustrative. It means that even if the contracting authority is not listed in the Annex 1, it will be covered by the GPA. Than the Annex 1 states that for the goods, services and suppliers of Ukraine the GPA covers procurement *by the following* central contracting authorities. It means that the list of central government contracting authorities of EU member states that is specified in the Annex 1 for Ukraine is exhaustive and represents the full extent of the EU coverage commitments. It means that if contracting authority is not listed in the Annex 1 it will not be covered by the GPA.

Conclusion

Despite the fact that the opening of public procurement markets within the EU-Ukraine Association Agreement is related to the degree of approximation of Ukraine's legislation to the EU requirements, as well as the positive decision of the Committee on Trade, Ukrainian suppliers already have the right to participate in the EU public procurement on the basis of non-discrimination principle, which is due to obligations under the GPA. Within the framework of the EU-Ukraine Association Agreement, Ukraine has access to larger volumes of procurement, firstly, because of lower, however not substantially, thresholds from which the principles of non-discrimination and free access to the market begin to apply. Secondly, the opportunities of Ukrainian suppliers are limited because the EU within the framework of the GPA secured a

positive list of goods and services which are covered by the GPA. This means that before deciding to participate in the EU procurement, Ukraine has to check whether the relevant goods and services are covered by the GPA. As a general rule, the EU main portal with information on procurement that exceeds the thresholds set out in the EU procurement directives, publishes contract notices which indicate whether the procurement is covered by the GPA [8].

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Professional Health of Teachers: Illusions and Reality

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Abstract – The results of the research were shown in the article, which proved negative tendencies in the teachers' psychological condition, a low level of possessing techniques of relieving psycho-emotional stress, high level of the tendency to stress. Strategic objectives and specific ways of preserving and strengthening occupational healthwere defined.

Keywords – occupational health, teachers, occupational stress, preserving and strengthening of the occupational health, occupational stress resistance.

Introduction

A work of a teacher belongs to the complex, stressful, tensed in psychological terms. There are certain objective reasons for this: multifunctionality of socially responsible pedagogical activity, high density of interpersonal contacts, communicative and information overloads, high nervous and emotional stress, the need to perform a large amount of work in a time limit, a large number of risk factors, stress factors which are constantly present in a work of a teacher, affect his well-being and quality of professional activity. Teachers have a very high risk of mental and somatic reactions to stressful situations at work. Constant overexertion of the mental and physiological functions of teachers leads to disability, the development of a condition that is characteristic of occupational stress. Occupational stress is a serious threat to occupational health.

The main feature of occupational stress is the absence of strong stimuli and the presence of a large number of small, constant (or for a long time) active stimuli affecting a person. After some time the cumulative effect of this influence leads to stress phenomena [12, p. 72]. In the scientific literature, there is even the concept of "teacher stress", which is interpreted as "the experience of unpleasant emotions and physical pain, which arises in the event of a threat to the well-being of the teacher, or when his ability to deal with urgent problems is exceeded" [8, p. 182]. The manifestations of stress in pedagogical activity is frustration, anxiety, exhaustion, emotional burnout.

In recent years, there have been many works that focus on the preservation and enhancement of occupational health, prevention of occupational stress of teachers, the formation of stress resistance of the specialist (O. Baranov, N. Vodopianova, T. Zaychikova, L. Gowel, V. Kaloshyn, L. Karamushka, S. Cartwright, K. Cooper, O. Markovets', R. Rozov, N. Samoukina, Y. Shcherbatykh, et al).

In the research of many scientists (V. Bobricka, T. Boychenko, Y. Boychuk, N. Bulatevits, N. Nazaruk, N. Rybachuk, et al.) It is noted that with the increase of work experience at school, the health of teachers deteriorates, the number of educators with psychosomatic disorders and chronic diseases grows up, and emotional burnout resulting from prolonged occupational stress increases.

Teacher occupational health is neither a priority at the preparatory stage in higher education institutions nor at the pedagogical level. Occupational health remains unaddressed by the School Psychological Service, the administration of the General Secondary Education Institution. In some institutions of postgraduate pedagogical education, there are attempts to introduce author's programs of information-prophylactic and physical-fitness orientation, which focus on the formation of a healthy lifestyle of teachers. Teachers' health concerns are mainly based on hygienic, psycho-hygienic and physical education approaches.

New approaches are necessary to address the challenges of preserving and enhancing the occupational health of teachers, to encourage educators to maintain their health fundamentally. Teachers need to look at themselves as a complex holistic system, take on the work of self-organization in the field of occupational health based on the principles: "know yourself, create yourself, help yourself, recover your health", "health – through a smart way life".

Therefore, the urgent problem of psychological and pedagogical science is the preservation and enhancement of teachers' health. In the focus of attention of scientists should be an educator with his far from the ideal state of occupational health, which is constantly deteriorating when interacting with modern "difficult" children, their ambitious and pretentious parents, not always friendly colleagues at work.

An important condition for providing the professional health of the teacher is a high level of motivation to carry out health activities, emotional strengthening of the body, prevention of excessive stress (distress). Such aspects have not yet been adequately reflected in the psychological and pedagogical literature and are poorly understood. Today, research on preventive measures, ways to preserve and enhance teachers' occupational health and increase their level of resilience are needed. To address these issues, it is important to study the professional health of educators, the characteristics of their internal picture of occupational health.

The purpose of the study is to identify the level of teachers' awareness of their occupational health, the depth of their motivation to exercise health, to study the characteristics of the internal picture of occupational health, the level of occupational stress, determine ways to preserve and strengthen the occupational health of teachers.

Methodology of Recearch

General Background of Research.

The professional health of the teacher is defined as an integral characteristic of the functional state of the organism, the global mental state of the person, characterized by the dynamic harmony of internal experiences and the related efficiency and success of the pedagogical activity, the ability to withstand the negative factors that accompany this activity [9, p. 208-209].

In the psychology of health, the internal picture of health is interpreted as a special attitude of the individual to his health, which is expressed in the awareness of his value and actively-positive efforts to improve it [11, p. 437]. V. Ananiev defined the internal picture of occupational health as self-awareness and self-knowledge of a person who is healthy [1]. The internal picture of occupational health reflects the individual's perception of health in general and his health in particular.

In the context of our research, it is important to take into account scientific approaches to the causes of occupational stress, which is a serious threat to occupational health. The occurrence

of occupational stress is caused by external factors (features of professional activity) and internal factors (features of the teacher's personality). Occurrence of occupational stress, according to L. Gowel [4], influence the personal and behavioral characteristics of a person.

Among them, first of all, there are such as: stubbornly striving to achieve intended, but usually unclear goals; great desire and willingness to compete; a constant desire to be recognized and to advance in your career; continuous performance of many different functions in terms of time limit; tendency to increase the pace of performance of their functions; unusually high speed of mental and physical reactions. A significant influence on the character of the development of stress, depth and consequences of its experience has individual characteristics of the person: optimism, sense of humor, strong-will qualities, kindness, self-esteem, self-control; the level of personality anxiety, neuroticism, uncertainty tolerance, type A behavioral pattern [11, p. 499]. Occupational stress is also determined by personal ambition, a subjective way of teacher professional development and self-realization [13].

Scientists present the overcoming the occupational stress in the form of prompt and preventive response. Operational stress management is interpreted as mastering behaviors to relieve stress, preventive coping – as shaping behaviors to avoid stress [2, p. 331]. Behavioral patterns contribute to, or on the contrary, impede the success of coping with occupational stresses, and which may be constructive and non-constructive. Health stress management is active and prosocial [12].

The main psychological indicators of occupational health are emotional well-being, occupational stress resistance, and satisfaction with pedagogical activity. That is why they were the focus of our research. 180 Teachers of Ternopil Region (Ukraine) participated in the study. The survey included teachers from urban and rural schools.

Instruments and Procedures.

In view of the above, the following techniques were used for the study: 1) a questionnaire developed by us to study the general health status of teachers; 2) the method "Accumulation of emotional-energy charges directed at himself" (by V. Boyko, author of the modification E. Ilyin) [6, p. 513-514] to detect the hidden emotional tension of teachers; 3) an adapted version of J. Jenkinson's technique for determining stress predisposition [12, p. 185-186]; 4) questionnaire of C. Spielberg-Y. Hanin, developed for the estimation of reactive and personal anxiety [3, p. 89-91]. It is worth mentioning that the implementation of these methods doesn't consume much time.

The questionnaire developed by us contains 18 questions, aims to reveal the level of the teachers' awareness of their occupational health state, the peculiarities of their motivation to healthy activity, the internal picture of occupational health, the state of emotional well-being. The questionnaire contains questions that imply self-esteem by teachers of their general health (answer options: excellent; good; satisfactory; unsatisfactory), attitude to their health (answer options: indifferent; my health worries me on a case-by-case basis; I am concerned about my health even when I feel well; I strive to maintain and strengthen my health); to find out if their lifestyle can be considered healthy (reasonable), or whether their health is hindering productive professional activity. Teachers should indicate which diseases they are predisposed to, what chronic conditions they have, and how they address health problems.

The second block of the questionnaire was aimed at: identifying what emotional state (mood) prevails with teachers at school (answers are stable positive, cheerful; unstable, often positive; unstable, often negative; negative, depressed); whether they feel psycho-emotional

stress at school; how easy it is for them to manage their emotions, to manage themselves in situations of professional interaction; have the techniques of relieving psycho-emotional stress.

The next questionnaire block is aimed at finding out whether teachers have the opportunity to receive timely psychological help in solving their personal and professional problems; what measures they take to improve their mental health, relieve emotional stress; how teachers solve psychological problems arising from their professional activities; whether the school has facilities for teachers to rest. To trace the link between teacher well-being and job satisfaction, the questionnaire is "Do you have a desire to change your profession? If so, for what reasons?"

The use of the method "Accumulation of emotional-energy charges directed at himself" (AEECDAH) (by V. Boyko, author of the modification of E. Ilyin) [6, p. 513-514] allows revealing hidden emotional tension of teachers. Respondents are invited to carefully read the 18 proposed provisions and express their attitude to them (put a "+" sign in the answer form, if the statement is in agreement, a "–" sign if they do not agree). There is 1 point for each positive answer. Less than 6 points – no emotional tension; 6-13 points – the average degree of expression of emotional tension; 14-18 points – a great hidden emotional tension. J. Jenkinson's technique for determining a person's susceptibility to stress [12, p. 185-186] involves choosing one of three options for answering each of the 20 questions ("yes" – 2 points; "something average" – 1 point; "no" – 0 points). The number of points was determined by the level of the tendency to stress. Up to 9 points – low tendency to stress; 9-12 points – average stress tendency, 13-15 points – neutral zone; 22-25 points – quite high tendency to stress; 26-40 points – high tendency to stress.

C. Spielberger–Y. Hanin questionnaire (SH) [3, p. 89-91] is aimed at the estimation of reactive and personal anxiety. Personal anxiety is observed as a relatively stable individual quality of the personality, that characterizes the degree of his/her anxiety, emotional tension due to the action of the stress factors. It characterizes the tendency of a person to perceive a great variety of situation as threatening, to react to them with a state of anxiety. The indicators of high personal anxiety give an imagination about a high possibility of the appearance of the anxiety state in the situations, where it is said about the estimation of the subject's competence, his readiness, etc. Reactive anxiety – is a state of a person, that characterizes the degree of his/her anxiety, worrying, emotional tension and develops according to a certain stressful situation.

Respondents need to read every from 18 given questions attentively and to cross out the appropriate number on the right depending on how they feel at that moment. Similarly, they were asked to answer 18 questions about how respondents most often feel. Indicators of reactive and personal anxiety are calculated using special formulas [3, p. 89-91]. If an integral indicator of reactive anxiety is up to 30 points, it shows a low level of reactive anxiety; from 30 to 45 points – medium (mild) level; more than 45 points – high level. The scale for determining the level of personal anxiety is similar.

Result of Research

The results of the study show that most educators interpret occupational health as a psychological state of being, a willingness to perform functional duties, while others understand it as a balance, inner peace. Teachers have noted the following diseases: diseases of the cardiovascular and nervous systems, digestive organs, disorders of cerebral circulation, osteochondrosis, etc. Almost all the interviewees develop diseases on the background of emotional instability. Deterioration of health indicators is observed in those who have more than 15 years of schoolwork.

When assessing their overall health, most educators (66,1%) chose the "satisfactory" answer. The option "excellent" was not chosen by any respondents, the option "good" was chosen by 55 teachers (30,6% of respondents), 6 teachers (3,3%) rated their health status as unsatisfactory. In this case, teachers, when ill, in most cases, the sick leave is rarely taken (52,8% of respondents), almost never – 32,2% They explain the reason for this in the following way: "I believe that the disease will go away by itself", "I do not pay attention to the condition of health","no time". And a heightened sense of responsibility forces the teacher to go to work even when it is necessary to take sick leave. Only 18,3% of respondents always seek qualified health care.

According to the teachers, their health condition hinders productive professional activity: 8 teachers have answered "yes", 104 – "more yes than no", 45 – "more no than yes" – 45; "no" – 18, "difficult to answer" – 5. Answering the questionnaire "Do you have the opportunity to get timely psychological help in solving personal and professional problems?" 171 teachers (95%) chose the option "no" and the rest – "more likely not". Most teachers noted that in the school where they work, there are no conditions for rest, relieve emotional tension. Only seven educators indicated the availability of appropriate rooms at the school, in particular, rooms of psychological discharge, rooms of spirituality. The results of the research certify the negative tendencies in the psychological wellbeing of teachers. Only 32 of the 180 teachers surveyed (17,8%) have a strong positive attitude at school. It is worth noting that 127 teachers (70,5%) are in a variable mood at school. They noted the existence of disturbances in their own emotional sphere (bad, depressed mood, irritability, tension, anxiety, difficulty in managing their emotions). In 11,7% of the surveyed teachers, negative, depressed condition prevails at school. They do not have the techniques of relieving psycho-emotional stress. The analysis of the answers to the questionnaire "Can you call your lifestyle healthy (reasonable)?" Shows that only 5,0% of the respondents answered in the affirmative, slightly more than half (52,2%) chose "faster than not". It is worth noting the irresponsible, "negligent" attitude of many teachers to their health. Only with illness or a sharp deterioration in physical health, a prophylactic examination forces them to see a doctor. It strives to maintain proper health at its proper level, retaining only one in the twentieth teacher (5,0% of respondents) to keep a "professional form".

It is worth noting that 14 teachers (7,8% of all surveyed) stated that very often they had a desire to change their profession, 35 teachers (19,4%) never sought to change their profession, and the remaining – 131 (72,7%) – chose yes, sometimes or very rarely. The reasons for wanting to change the profession are referred to by teachers as: "an extremely large number of requirements for the teacher, his activity", "the complexity of working with modern children"; "poor health"; "fatigue", "constant mental stress", "exhaustion", "overload", "financial problems", etc. Some teachers have quite interestingly formulated the causes of the disappointment in pedagogical activity: "annoyed students", "exhausting and difficult", "a series of troubles in the teaching staff", "great demands – low salary", "lack of payback", etc.

Young teachers are more likely to want to change their profession, indicating the reasons: "difficult psychologically", "tired of monotony", "lack of time", "divergent views with the administration", "underestimated leadership", "over-organized at school". Male teachers are more likely to cite financial problems and lack of proper working conditions as reasons for changing professions.

The table 1 shows the results of teachers' answers to some of the questionnaires.

Table 1

Results of teacher surveys regarding their occupational health

Questionnaire Questions	Answer Options									
	Yes	%	More yes than no	%	More no than yes	%	No	%	Difficult to answer	%
1. Do you experience psycho-emotional stress from working at school?	138	76,7	28	15,5	14	7,8	–	–	–	–
2. Do you have the techniques of relieving psycho-emotional tension?	–	–	54	30,0	99	55,2	24	13,3	3	1,8
3. Do you have the opportunity to get psychological help in solving your personal and professional problems?	–	–	–	–	9	5,0	171	95,0	–	–
4. Can you call your lifestyle reasonable?	9	5,0	94	52,2	57	31,7	14	7,8	6	3,3
5. Does your health interfere with your professional activity?	8	4,4	104	57,8	45	25,0	18	10,0	5	2,8

Data on the use of the C. Spielberger–Y. Hanin (SH) questionnaire complement the picture of occupational health. The results of the study showed manifestations in teachers of medium and high levels of personal anxiety (44,4% and 30,5% respectively), as well as the dominance of high levels of reactive anxiety (60,6% of respondents). The revealed indicators of teachers' reactive anxiety confirm the high level of teachers' psychiatrization, which is characterized by a painful response to criticism and remarks addressed. Indicators of high personal anxiety give an idea of the high likelihood of anxiety in situations where it is an assessment of the subject's competence, preparedness, etc.

Using the method of "Accumulation of emotional and energy charges directed at oneself" showed that 83,5% of respondents found a great hidden emotional tension (72,5% of respondents scored 16 points, 11,0% – 17 points when the maximum number of points is 18). The average level of expression of emotional tension is characteristic of 11,8% of the surveyed teachers. No respondent scored less than 6 points (no emotional tension). It is worth noting that almost half of the teachers (47,7%) chose the answer "yes" to the questionnaire "Are you most often

dissatisfied with yourself or your job". Almost a third of respondents (55 educators) answered yes to the question "Do you usually feel tight, tense".

The results of the use of the Jenkinson method confirmed the high tendency of teachers to stress (Fig. 1). 13 respondents (7,2%) found a low tendency to stress; 104 respondents (57,8%) had an average tendency to stress; 22 respondents (12,2%) have a very high tendency to stress; 34 respondents (18,9%) are highly prone to stress. Seven of the respondents (3,9%) scored from 13 to 15 points, that is, they were in the neutral zone of the tendency to stress.

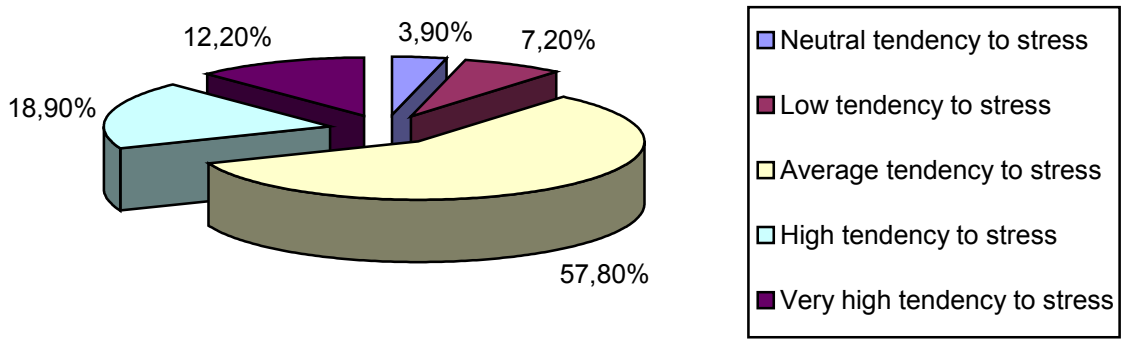

Fig. 1. The division of teachers according to the level of the tendency to stress (in %)

Most of the surveyed teachers stated that they were not able to withstand stress, overcome the negative impact of distress on their own personality, did not have enough information about ways to build stress resistance, preservation technologies and promote occupational health.

Discussion

The results of the study indicate low levels of occupational health, high morbidity of teachers, their emotional stress, low level of motivation, low level of self-regulation of emotional states, high tendency to occupational stress, high level of anxiety, and overall lack of competence in health issues. Therefore, it is extremely important to identify new facets of teacher professional health.

An effective way to protect against occupational stress is to increase the level of occupational stress of teachers, which determines the ability to withstand stress, negative factors of pedagogical activity, stressful situations, overcome professional difficulties without harm to health and work, find their resources in difficult conditions [10, p. 60]. Increasing a teacher's professional resilience is associated with finding resources to help him or her deal with the negative effects of stressful situations. The effectiveness of combating professional stress is determined by several personal characteristics, among which the decisive role belongs to the motivational sphere of the teacher. In the perspective of our study, it is important to state that actively coping with stress, combined with the positive use of social contacts, enhances teacher resilience [12, p. 231].

Taking into account the aforementioned and based on the analysis of the results of the conducted research, the strategic tasks for preserving and strengthening the professional health of teachers were highlighted: increasing the level of professional stress resistance, developing the skills of mental self-regulation; reducing anxiety; mastering constructive coping strategies, technologies of self-rehabilitation, psychotechnology of self-healing, development of health-saving competence.

Activity to preserve and promote the occupational health of teachers should aim at: increasing teachers' interest in occupational health as a professional value and ways of providing

it; increasing awareness of occupational health and smart living; mastering ways to implement health-saving techniques; teachers' self-knowledge and self-development; the activity and creativity of teachers in finding and creating their own health systems, their own experience of maintaining optimal health status; assisting teachers in overcoming obstacles to a smart lifestyle. Important aspects of work in this aspect are the prevention of occupational stress, the correction of chronic stress of professional origin, the prevention of emotional burnout.

Today, it is necessary to shape such a quality of teacher's personality as resilience, that is, the ability to maintain resilience under the influence of external and internal threats without losing the pace of development [7, p. 160]. Resilience refers to a dynamic process that implies a positive adaptation in the context of significant problems [5]. Scientists are developing technologies of social and psychological resilience to overcome the negative consequences of encountering adverse circumstances and professional difficulties, to prevent destructive behavior, to ensure the quality of later life and professional activity. These technologies are not yet very actively implemented in the occupational health professions of teachers.

Conclusion

Preserving and promoting the professional health of the teacher is a strategic task of modern society and the new Ukrainian school, an urgent problem of pedagogical and psychological science.

In order to preserve and enhance the occupational health of teachers, it is important to implement the following aspects of the activity: 1) the development of the emotional-value, responsible attitude of teachers to occupational health; 2) increasing the level of motivation for personal and professional growth, maintaining the "professional form"; 3) developing the subjective position of the teacher as a carrier of a smart lifestyle; 4) purposeful activity of the school psychological service for preserving and promoting the professional health of teachers; 5) participation of teachers in pieces of training for personal and professional growth, anti-burn training, anti-stain training; 6) creation of a psychologically safe educational environment in an educational institution aimed at functioning of a harmonious, psychologically healthy personality, able to withstand the negative factors of pedagogical activity, constructively overcome professional difficulties with the least losses for health; 7) reasonable organization of the teacher. We see the prospects of scientific exploration in the development of the system of work of the institution of general secondary education for ensuring the professional health of teachers, which should cover monitoring of their health status, psychological support, supervision in pedagogical activity, preventive and improving measures, use of modern technologies of preservation and strengthening of professions health. They need to introduce technology to increase the level of resilience, to prevent emotional burnout, and to develop social and psychological resilience in the area of occupational health education for educators in managing the skills of crises with the least emotional or psychological losses.

At the state level, it is urgent today to address the issue of creating and implementing a comprehensive program of teacher professional health that would include medical, psychological, pedagogical, psychotherapeutic aspects of care.

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Factors affecting the choice of a tutor to prepare for EIT in Ukraine

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Abstract – The role and relevance of tutoring as a form of preparation for EIT in Ukraine are highlighted. The results of a sociological survey of eleventh-graders and frashmen on the attitude to tutoring as a form of preparation for EIT are analyzed. The sociological analysis of the factors affecting the choice of a tutor to prepare for EIT in Ukraine is conducted.

Keywords – external independent testing (EIT), tutoring, tutor, eleventh-grader, freshman, concordance coefficient, ranking of factors.

Introduction

The problem of education has been and remains an issue at all times in any society. Teachers, parents, scientists, politicians are trying to answer the question how to make the learning process effective and how to improve the quality of education. Nowadays, more and more parents are calling on private tutors for help in improving the quality of education and their children's educational attainment.

In the past few years, this phenomenon has become widespread, which allows us to assume that tutoring is becoming a part of the learning process. Previously, tutoring was considered as a phenomenon necessary for learning at a certain period, for example, due to a lower educational attainment because of illness, but now tutors often accompany a child throughout the entire period of education – from preparing for school to entering higher education institutions.

The popularity of the tutor is increasing rapidly. On average, the demand for tutoring services on the Internet is growing by 15% every year [1]. The the sociological survey data "Dynamics of Ukrainian's Attitude to EIT" conducted by the Sociological Group "Rating" from May 3 to 8, 2018 show that more than a half (52%) of those who personally or whose children passed the exam taking the tutors' services during the preparation for the exams, 43% did not use such services [2]. For comparison, only 15% did not personally use the services of tutors to prepare for EIT in 2016 and did not have children and children of relatives or acquaintances who called on the corresponding services to tutors (there were 26% in 2015) [3].

Sociological analysis of the factors affecting the choice of a tutor to prepare for EIT in Ukraine

We conducted a survey among eleven-graders who attended tutors during the survey and freshmen who were attending the target EIT to evaluate and analyze the factors affecting the choice of a tutor to prepare for EIT. This survey was conducted in January-April 2019. In total, the sociological survey was attended by 100 eleventh-graders from twelve schools: eight schools in Lviv, two schools in Drohobych and one school in Stryi, and 200 first-year students from the following educational institutions: Lviv Polytechnic National University, Ivan Franko National University of Lviv, Lviv Institute of Economics and Tourism, Ukrainian National Forestry University, Drohobych Ivan Franko State Pedagogical University.

The interviewing method was a questionnaire, which provided that respondents should fill out the questionnaires with pre-prepared questions. The response results are given in Table 1. It should be noted that we ranked, which respondents noted in their answers, and turned into points in the following way: 20 points for the most affecting factor, 1 point for the least affecting factor.

Table 1

Respondents' answers results to the questionnaire: "Rank the factors affecting the choice of a tutor to prepare for EIT"

List of factors	Total points			Average value of points			Factor rating according to		
	Graduates' answers	First-year students' answers	Sums of answers (gr.2 + gr.3)	Graduates' answers (gr.2 / 20)	First-year students' answers (gr.3 / 20)	Sums of answers (gr..4 / 20)	Graduates' answers	First-year students' answers	Sums of answers
1	2	3	4	5	6	7	8	9	10
The desire to get better EIT results	1910	3562	5472	19.1	17.81	18.24	1	3	3
Overloading with homework received at school	724	1026	1750	7.24	5.13	5.83	14	16	16
Time to rest	802	2004	2806	8.02	10.02	9.35	13	11	11
To have time to go in for sports, music or other hobbies	1124	2384	3508	11.24	11.92	11.69	10	9	10
Low level of knowledge in this subject	1786	3976	5762	17.86	19.88	19.21	2	1	1
Quality of teaching at school	1544	3386	4930	15.44	16.93	16.43	5	4	4
Learn something new	706	1818	2524	7.06	9.09	8.41	15	12	13
Financial reasons	1768	3766	5534	17.68	18.83	18.45	3	2	2
Average mark (achievement)	220	250	470	2.2	1.25	1.57	19	20	20
School achievement level	158	634	792	1.58	3.17	2.64	20	18	18
Place of residence, time of getting to the tutor	1458	2978	4436	14.58	14.89	14.79	6	6	6
Internet access	450	832	1282	4.5	4.16	4.27	17	17	17
Teachers' recommendations	534	1224	1758	5.34	6.12	5.86	16	15	15
Friends, classmates' recommendations	994	1602	2596	9.94	8.01	8.65	11	13	12
Parents' requirement	1226	2576	3802	12.26	12.88	12.67	9	8	8
Individual approach	974	1390	2364	9.74	6.95	7.88	12	14	14
Ability to schedule teaching time	1340	3168	4508	13.4	15.84	15.03	7	5	5
Studying the material according to the EIT programs requirements	1620	2776	4396	16.2	13.88	14.65	4	7	7
Assurance and increased confidence in passing EIT	1318	2212	3530	13.18	11.06	11.77	8	10	9
Teacher's pressure	344	436	780	3.44	2.18	2.6	18	19	19

Source: the results of the authors' own survey

Using mathematical and statistical analyzes, we can give an interpretation for the results. It is normal that the average value of the opinion form several respondents will be more reliable than the friend's answers, and the larger the number of respondents, the more reliable is the result. The reliability of the respondents' answers is assessed using the concordance coefficient, which characterizes the degree of agreement between the respondents. The more consistent is

respondents' answers, the more reliable is the estimates. The concordance coefficient is calculated using the formula [4, p. 251]:

$$W = \frac{\sigma_a^2}{\sigma_{\max}^2} = \frac{\sum_{i=1}^{m}\left\{a_i - \frac{1}{2}\cdot n\cdot(m+1)\right\}^2}{\frac{1}{12}\cdot n^2\cdot m\cdot(m^2-1)}, \qquad (1)$$

where σ_a^2 – actual variance (standard deviation) for the final estimates provided by respondents; $\sigma_{\max}^2$ – variance of final estimates provided that the respondents' opinions completely coincide; a_i – total score obtained by the *i*-th object; m – number of valuation objects; n – number of respondents.

The materiality (statistical significance) of the concordance coefficient is checked by comparing the value $\chi^2_{calc} = W\cdot n\cdot(m-1)$ з $(m - 1)$ the number of degrees of freedom and with confidence 0.95 with table value χ^2 of Pearson's criterion. If $\chi^2_{calc} \geq \chi^2$, then the coefficient W is significant, if $\chi^2_{calc} < \chi^2$, then it is necessary to increase the number of respondents.

The magnitude of the concordance coefficient for the answers of eleventh graders is $W_{e.g.} = 0.74$, freshmen – $W_f = 0.77$. In all cases, the value of the indicator tends to 1, that means the thoughts of eleventh graders coincide in more than 74%, freshmen – 77%, therefore, the feasibility of further analysis, given the answers of the respondents, is justified.

The results of comparing the calculated value χ^2_{calc} for (20 – 1) degrees of freedom for eleventh graders and freshmen is more tabular. Therefore, we can assume that the opinions of respondents are well agreed in assessing the influence of factors on the studied object.

The results of ranking factors according to the degree of influence on the decision of eleventh graders to choose a tutor to prepare for EIT give the following results. The factors affecting the decision-making by eleventh graders are the following: low level of knowledge in this subject, financial reason and desire to get the best results in EIT. These factors are fully justified. The main purpose of tutoring is to obtain additional knowledge in the subject where students have a low level of knowledge. Until 2007, tutoring was not as popular as today, because the system of admission to a higher education institution has changed. If, before, the opportunity to graduate from HEI depended more on family relationships, agreement by giving bribes, the number of applications for this specialty, the subjective decision of the admissions committee members (especially when the entrance exam was taken orally, or there was a slight differentiation in the entrance results – that is, a large number of entrants could have had an «excellent» mark and their chances mainly depended on the factors other than knowledge), the complexity of the exam (since each HEI composed introductory tasks independently), today, the probability of entry is determined by the number of points scored on the EIT and placement in the rating list. The only legal way to get high scores on EIT is to have a sufficient level of knowledge. The best EIT results are the great opportunities and better prospects for the applicant.

The financial situation of the parents of the eleventh graders has an important influence on decision-making – this is the aggregate level of family income, the cost of tutoring courses, which varies depending on the academic discipline and the region. On average, one hour of

Ukrainian language classes costs 80-120 UAH; mathematics – 100-150 UAH; history – 70-100 UAH. The prices range for the English classes is from 100 to 300 UAH for one hour [5].

In cash equivalent, each family spends on average about $ 380 once a year for individual tutors. During 2015, 500,000 Ukrainian studied foreign languages outside of school, for which they spent about $ 700 million. At the same time, $ 600 million is the cost of tutors, and the rest is the profit of the courses [1]. According to scientists, preparation for EIT-2018 with tutors in three subjects for eight months costs a minimum of 32000 UAH [6, p. 14].

The average score (success), the level of school achievements, the pressure from the teachers are less affecting for the choice of a tutor.

In the campaign 2018-2019, the schoolchild's studies are completely leveled by minimizing or unrecorded average grade from school-leaving certificate. For example, the coefficient ranged from 0.05 to 0.1 at Ivan Franko National University of Lviv and Taras Shevchenko National University of Kyiv depending on the chosen specialty. Higher educational institutions of Ivano-Frankivsk, in particular the Vasyl Stefanyk Precarpathian National University and Ivano-Frankivsk National Technical University of Oil and Gas offered multiplication coefficient for the average score of the certificate, which did not exceed 0.1. The decision to reduce the role of "school knowledge" was approved by the Ministry of Education and Science of Ukraine on October 13, 2017. The reason for such reforms is that the certificate does not always reflect the real level of knowledge of students [7]. In many universities, the grade point average was not taken into account. In our opinion, this decision leads to a worsening of the students' study in those academic disciplines that do not have the form of the EIT, since the results of the certificate will not be taken into account upon admission. The situation is that some school subjects are important and ther is no need to study the rest disciplines.

It can be assumed that due to the absence of those, who received additional points for the awards in scientific contests, among the respondents, the «level of school achievements» factor was low rated, that is, respondents did not give due attention to this answer option. Pressure from teachers is not a significant factor affecting the need to work with a tutor, reflecting a conscious and own choice (or under the influence of parents or friends) of a student to receive additional classes with a tutor.

Conclusion

The introduction of such a form of assessing for the level of knowledge of graduates in Ukraine as external independent test (EIT) made tutoring increasingly relevant as an auxiliary form of private education and preparation for this form of control. Despite the fact that students receive education in educational institutions on a free basis, have the opportunity to use the library for free, the availability of a large number of educational resources on the Internet (electronic manuals, video and audio clips, presentations, examples of solving practical problems and tasks, etc.), tutoring is becoming increasingly relevant, although it is expensive.

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New Profit Allocation Model Under BEPS 2.0

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Abstract – On 31 May 2019, the OECD published the Program of work to deal with the tax challenges arising from the digitalization of the economy [1], [2], [3]. The main purpose of the Program is to develop new principles of taxation in the digital world, which are called by many as BEPS 2.0. It is planned to finish the Program at the end of 2020. The document considers the three different methods of profit allocation, which is earned on digital sales, for the purposes of its taxation in the jurisdictions where a seller does not have physical presence (hereinafter – market jurisdiction). In this article, the author proposes the implementation approach for the one of three methods and gives an answer to the problematic questions of application of that method, raised by the Program.

Keywords – Digitalization, digital sales, profit allocation, routine profit, non-routine profit, value chain analysis, profit level indicator (PLI), multinational enterprise (MNE), assets and risks, arm's length principle.

Introduction

The Program defines the new rules for profit allocation, which assumed apportionment and further allocation of the profit share (and corporate taxes respectively) of the seller on the "market jurisdiction" or, in other words, the jurisdiction where clients are located but profit is not allocated due to the lack of physical presence of the seller.

One of the three profit allocation methods proposed by OECD is Modified residual profit split method.

The MRPS method would allocate to market jurisdictions a portion of an MNE non-routine profit that reflects the value created in markets that is not recognized under the existing profit allocation rules.

It involves four steps:

- determine total profit to be split;
- remove routine profit, using either current transfer pricing rules or simplified conventions [4];
- determine the portion of the non-routine profit that is within the scope of the new taxing right, using either current transfer pricing rules or simplified conventions [4];
- allocate such in-scope non-routine profit to the relevant market jurisdictions, using an allocation key.

Given that the new methodology assumes the new profit allocation mechanism, it would significantly change the existent transfer pricing risk assessment models used by the tax offices and MNE. At the same time, the new rules have some difficulties with implementation, dealing with which is of the main objective of the Program.

Research results

The main principles, which are the basis for the Program (and for the methods respectively) are double taxation avoidance and value creation. Furthermore, the Program contemplates reducing compliance costs and tax disputes as well as establishing the unified approach to tax measure.

As of today, the main principles of transfer pricing risk assessment are described in the OECD Draft handbook [5]. The current risk assessment models work based on risk factor analysis. Among such risk factors are amount of transactions with law-tax counterparty, low profitability level, ongoing losses etc. In such models, MNE and tax offices track predefined indicators and compare them with the fixed thresholds during a process of tax risk probability assessment.

The new method of profit allocation would change traditional approaches to tax risk assessment for digital sales. For risk analysis instruments to be implemented, the tax offices and the MNE both should develop the distinct algorithm of profit allocation accordingly with the new methodology being proposed.

We further consider the issues on implementation of each step for MRPS and propose the practical solutions.

Step 1. Profit determination

Problem

The main issue raised in the Program is the profit amount to be allocated. The problem is the difference between accounting and tax profit itself and their definitions among other jurisdictions. Thus, the approaches to the profit calculation (e.g. allowances, tax loss carry forward etc.) in seller's jurisdiction can be different compared to one that is in market jurisdiction. Furthermore, there are several questions with regard to the profit indicator itself. Whether the consolidated or standalone seller's profit should be used? And another, whether accounting profit or its modified measure with tax adjustments should be considered?

Solution

As an amount for allocation it is proposed using the consolidated operating profit according to the audited financial statement under IFRS or US GAAP. The operating profit differs from earnings before taxes in that it does not include financial incomes and expenses, in particular interests. Such approach reflects the nature of trading (or distribution) profit, whose generating required less financial investments. It also unifies the discrepancies in tax differences for different jurisdictions, as different interest deduction limitations are the core tax adjustment for many countries. That approach is consistent with the selection of routine profit indicator in arm's length analysis for which, generally, operating profit is used.

Moreover, it is proposed using the consolidated profit the against standalone one, as the last may not include the part of profit being remained with other members of MNE, who perform the relevant market functions in the process of digital sales generation. As for the accounting standards, either IFRS (earnings before interest and taxes) or US GAAP (income from operations) are offered. Such an approach corresponds with the main principles laid down in the Program as well as underlines consistency between seller's profit base and the one that is allocated on "market jurisdiction".

Step 2. Routine profit calculation

Problem

The routine profit is part of the total MNE's profit, which is a reward for performing routine functions (e.g. contracting manufacture, administration, procurement etc.), managing basic assets (e.g. ordinary property, plant and equipment) and undertaking risks which is typical for that type of business (e.g. FX, commercial etc.). The difficulty of determining the share of routine profits of total profit is a particular business specific (business model), which lies in the features of the economic structuring of the value chain.

The same assets and functions in different MNE can create completely different value. Thus, the financial management function in MNE with a large loan portfolio has more important role then for the similar MNE operating on the same market but with low level of debt.

Solution

Dealing with a task of calculation the routine profit it is considered the following algorithm:

Stage 1. Value chain analysis

Stage 2. Classification of identified functions, assets and risks

Stage 3. Determination of profit generating driver

Stage 4. Determination of the matrix with figures of routine profitability

Stage 5. Calculation of routine profit

At the first stage, the value chain of particular MNE should be visualized, the result is shown in the Fig.1 [8]:

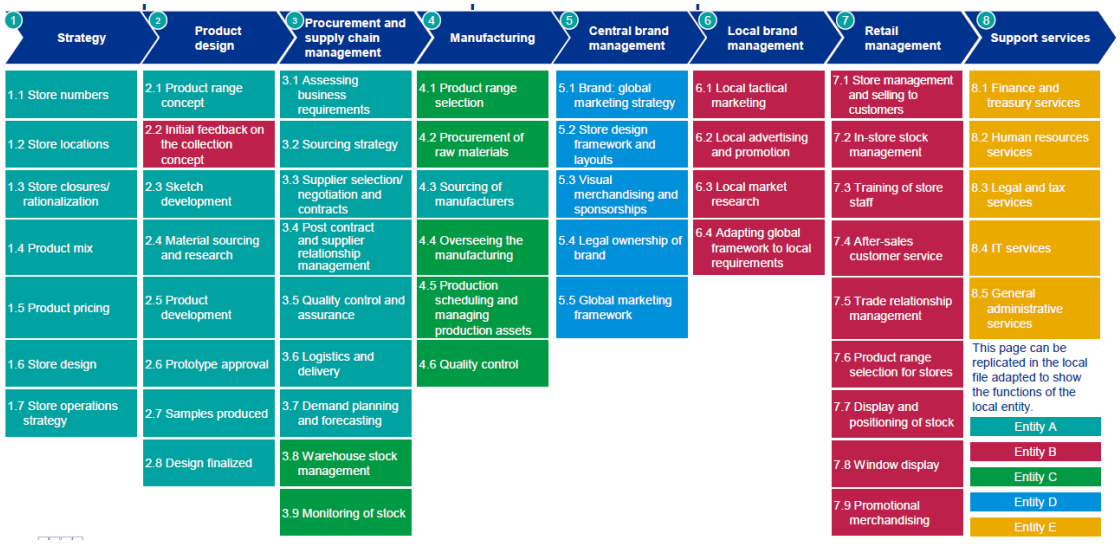

Figure 1. The value chain of particular MNE

At the next stage, the classification of the identified functions, assets and risks within each value chain element is carried out according to the degree of influence on profit generating process, namely, low, medium and high. The visualization of this process is the so-called heat map (Fig. 2) [8].

Figure 2. Heat map

Further, for each of the elements of value chain, we determine the main economic driver for value creation process, namely, capital, assets, costs, sales, personnel, etc.

Then, we carry out the benchmarking study of profitability level of the independent companies for different PLI and geographical markets. For the benchmarking we use the commercial databases of the company's financials [7]. The matrix can be realized as given in Table 1:

Table 1

Routine profitability matrix

VC element	Low	Medium	High
Region: Western Europe			
Business line: C10.5.1 - Operation of dairies and cheese making			
Strategy	5%	10%	15%
Product design	10%	15%	20%
Procurement	1%	3%	5%
Manufacturing	5%	7%	10%
Brand management	5%	10%	15%
Retail management	5%	10%	15%
Support services	1%	3%	5%

As a result, the elements of the formula for routine profit can be presented as follows:

VC element class – Procurement;

Market of operation – Western Europe;

Business line - Operation of dairies and cheese making;

Overall profit impact – Medium;

Profit driver – Full cost;

Median of AL PLI – 3%

The total routine profit is equal to:

$$TRP = \sum_{1}^{n} PDA_n \cdot ALPLI_n$$

TRP – total routine profit;

PDA – profit driver amount;

ALPLI – arm's length PLI

N – number of value chain elements.

Step 3. Non-routine profit calculation

Problem

Non-routine profit is that part of total consolidated profit, which remained after the allocation of the share of routine profits from the total. This is the profit that is generated, generally, due to non-ordinary tangible and intangible assets, such as a brand, customer base, certain know-how, etc. The allocation problem in this case is the determination of the contribution of each of these assets in the process of generating this profit. In our case, the task is also the allocation of non-routine profits that fall exactly on market jurisdictions.

Solution

The following algorithm is proposed:

- Identification of the assets used in value chain across its elements;
- Assets classification as routine and non-routine with regard to the nature of their impact on value creating process;
- Market value assessment of routine and non-routine assets.

Asset identification is carried out as part of a functional analysis. Generally, the results of such an analysis are reflected in the MNE's Master File.

Those assets that support the normal functioning of value chain without creating significant added value are classified as routine.

Assessment of the market value of non-routine assets is carried out using generally accepted valuation approaches regulated by the International valuation standards. For example, for intangible assets can be used excess earnings method, premium profit method or distributor method [6]. For tangible assets, the book value or the fair value according to the accounting standards can be used.

The total amount of non-routine profit is allocated between the respective assets pro-rata to their market value.

Step 4. Profit allocation to relevant market jurisdiction

While considering the allocation key it should be taken into account that market and sovereign risks are different for each particular market.

If as allocation key sales of goods had been taken it would not take into account a sales margin in that market as a result, for example, in sovereign risk.

As an allocation key, it is proposed using arm's length gross profit indicator for the relevant market, which is based on the benchmarking study results received at the previous stages.

In this case, the formula for the allocation key will be the following:

$$AK_m = \frac{R_n \cdot GPI_m}{NRMP}$$

AK – allocation key;

R – revenue amount;

GPI – arm's length gross profit indicator;

NRMP – non-routine profit allocated to market assets;

m – particular jurisdiction.

Given previous steps, the allocated profit is calculated as follows:

$$AP_m = (COP - TRP) \cdot \frac{NRMA}{TNRA} \cdot AK_m$$

AP – allocated profit;
COP – consolidated operation profit;
NRMA – market value of non-routine market assets;
TNRA – total market value of non-routine assets;
m – particular jurisdiction.

Conclusion

In this article, we consider one of the new profit allocation method proposed by OECD concerning digital sales taxation in "market jurisdiction". We propose the possible solutions regarding the MRPS method application. The result is a conceptual framework in form of basic math model for MRPS calculation, which could be used by the tax offices and the MNE as an instrument for transfer pricing risk assessment in digital sales.

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Activities of knowledge brokers – paths and themes of analysis

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Abstract - The purpose of the research is both to show how knowledge brokers perform their activities and to prove that multidimensional approach is needed to discuss the topic. The adopted way of analysis allows the author to pinpoint interesting themes. The novelty of the research results from theoretical perspective that is used to comprehend described processes.

Keywords - knowledge brokers, knowledge transfer, knowledge creation, intermediary function, open innovation

Introduction

It is believed that forming innovative networks comprised of private enterprises and public research organizations can contribute to the development of lagging regions [1]. In order for knowledge exchanges to occur smoothly it is necessary that specialized intermediary organizations like centres of technology transfer, research institutes, scientific parks, chambers of commerce and industry or other regional and international institutions as well as points of contact engage in these processes as they are at least partly responsible for ensuring connections. Actually, it is possible to distinguish among these specialized intermediary organizations as many as 16 groups following a few criteria [2] that are to be explained later. What should be emphasized now is that because the requirement for open innovation to happen is that all stakeholders, experiments and early prototypes in real-world settings lead to new products and services, it is claimed that open innovation ecosystems should be based on factors like common values or common purpose-driven actions. Moreover, there are some additional requirements relating to the process like the potential for rapid scaling-up or the engagement of resources focused for impact. As a result, organization-driven or instrument-driven actions appear not to be a suitable fundament for the creation of innovations that require new skills. Indeed, the attention is also paid to the fact that e-skills training being focused to a large extent on skills for creating ICT systems cause that the dimension consisted of practices making innovation ecosystems work is omitted [3, pp. 9-10]. The issue is that there are two-sided technology platforms, application programming interface-based development, systemic approaches to innovation and increased use of digitalised data [4, p. 93] that all become factors on which the new collaboration models are built. Due to the fact that established value chains and strategies have been challenged by more and more complex configurations of products and services, companies have realised that in order to find needed competencies they have to collaborate with other organizations or customers [5, p. 93]. The possibility to define open innovation practices in the light of quadruple helix collaboration emerges, which is why the engagement of public sector, people as well as small and medium-sized enterprises and academia leads to the democratisation of the innovation process [6, p. 96]. The research question that emerges is related to how it actually happens that so many actors are able to work together. It can be assumed that some important mainly intangible resources need to be mobilized even when the barriers like specific features of resources and organizational prossess or geographical distance make it difficult for organizations to cooperate. At the same time, one can notice here that the interesting research area opens out from these tendencies and is actually related to the activities of the intermediary organizations (knowledge brokers to be continued) that have to support others in creating knowledge resources.

Theoretical background

By investigating the literature concepts like intermediary organizations or knowledge brokers appear to be emphasized as it is claimed that they should become central to the innovation ecosystem [3, p. 10]. But when requiring that they would be able to synthesise connections between themes, competencies and people do we need to pose the questions related to their attributes as well as to the ways in which they are expected to achieve their goals. It is necessary to add that some researches have already been conducted on the topic in Poland. Bąkowski and Mażewska [7-8] are focused on resources possessed by business support institutions that can be perceived as knowledge brokers. Some these institutions possess diversified technical equipment that apart from being made use of by given institution can serve its clients who are running their businesses [7, p. 20]. Later trends are believed to show that the development of infrastructure reflects strictly activities undertaken by these institutions, e. g. exhibition spaces begins to be created [8, p. 19]. What has also been shown is that people employed by these institutions are gradually replaced by different sub-contractors. On the one hand, undoubtedly it may cause that regional networks can be strengthened by more knowledgeable participants. On the other hand, instead of solving problems people employed by business support organizations may be more engaged by organizational tasks [7, pp. 22, 111]. Consequently, core competences of these institutions may gradually disappear. However, there still is not possible that all services will be rendered by people not directly employed by business support institutions [8, pp. 19-20]. Though it may appear to be surprising but the weakest source of financial resources is related to commercially undertaken activities, including profits possible to be gained from commercialization [7, pp. 23-25]. The activities on this field have not seem to change significantly through the years [8, p. 22]. What is a positive tendency is that more and more business support organizations become certified, actually it is justified to say about significant change that have occurred [7, pp. 27,28; 8, pp. 22-25]. Regarding external relations business support organizations have claimed that universities are considered by them as having the greatest impact on them [7, pp. 29-30]. It is claimed that when cooperation network consisted of enterprises that commercialize their research results and new technologies, scientific and research institutes as well as support institutions becomes to have international range, the view of its participants on how to conduct research becomes global and at the same time convergent with the current trends [9, p. 84]. However, researches have shown that support institutions really weakly cooperate with partners that operate within different regions or countries [7, p. 30].

Considering above-mentioned aspects related to making the infrastructure accessible to customers (a), directions for the development of infrastructure (b), contracting external people by business support institutions that look also for new partners (c), attention paid to commercial sources of revenue as well as growing importance of making use of different certificates (d), importance of mutually beneficial cooperation with regional partners (e) we may come to conclusions that it is worth analysing activities performed by knowledge brokers from the point of view of the model of a knowledge-creating firm [10] that appears to strongly echoe in further conceptualizations related to so called fractal organization [11]. Here knowledge is created through dynamic interactions with the environment and the organization can be considered as the organic configuration of various contexts named also as ba, that is an existential context or a place in which meaning is maintained and the knowledge shared, created and exploited [12, pp. 1001, 1006]. This is because here the assumption is that more important than legal boundary of a firm is how its various contexts (ba), both outside and inside the organization are synthesized.

Considering a firm as a dialectical being implies paying attention not only to the outcomes but also to the process of its knowledge-creating activities [12, p. 1006].

It appears that other kind of organizations can be described by the use of terminology proposed by the discussed model that can help researchers to interpret hitherto described aspects [7-8] from other point of view. As it has been shown few factors are taken into account then. The environment considered as an ecosystem of knowledge and multi-layered ba (c'[1]) which becomes a source for interpretation is built through dialogues and practices. The task involves making synthesis of all subjective views and intuitions accumulated by the daily practice. Contradictions when accepted and synthesized may become the source of knowledge that is expected to allow people to deal with the duality present in the reality. Indeed, there are important driving objectives, understood as some targets thanks to which knowledge creation is energized and directed together with creative routines which make it possible to foster creativity without neglecting the effectiveness (d'), knowledge assets like for example IT infrastructure, information system and other tools used to manage knowledge as well as trust and social capital (a'). What should also be emphasized, there is the requirement that individuals reflect on the meaning of their actions in order to revise it when necessary (b'). Besides the significance which is attached by knowledge brokers to the issues of exploiting regional resources for the benefits of whole region is emphasized (e'). Taking such a point of view is actually the excellent basis when preparing to interview people who deal with tasks involving knowledge brokering.

Research process and themes of analysis

In order to investigate the above-mentioned issues the multiple-case study method has been applied by the author. Because of the complexity of the topic and rather blurred character of boundaries between the phenomenon and its context this method appears to be suitable for making comparisons as to how activities of knowledge brokers are performed based on defined dimensions [13-14]. The research consisted of seven cases defined as activities undertaken by knowledge brokers which can include such as matching partners from private sectors or from private and public sectors, making complex knowledge more understandable for others or simply conveying important information as to where valuable sources of knowledge can be accessed. Each of knowledge brokers that are taken into account in the research strongly contributes to the creation of Regional Innovation Strategy of Silesia Voivodeship. What is also important during interviews that were conducted to collect suitable pieces of information respondents were able to present their understanding of how their organizations operate in the complex environment which is actually co-created by them. In order to deal with the analysis of single case related to each knowledge broker and next to perform comparative analysis as well as to look for main patterns enabling preparations of the final interpretations the author made use of different kinds of matrices and causal networks described in detail by Miles and Huberman [15].

Results of analysis relating to the level of dimensions that has already been mentioned are as follows**.** Regarding the attention paid to local channels of knowledge and the contribution to its development (a') knowledge brokers consider as being important issues of enriching local flows with knowledge coming from abroad. Then cooperating organizations can have more opportunities to find partners as well (II[2]). When utilized to greater extent local networks should allow actors to develop organizational competencies and to maintain the liveliness of local ties which may result in finding more sources of income in the future (I). Other organizations tend to

[1] Letters with apostrophes in parentheses refer to aspects previously described that are marked by letters without apostrophes. Of course, the terms described in the model of knowledge-creating firm cannot be fully explained by the references to these aspects, however, they are partle covered by them.

[2] Numbers in parentheses refer to investigated knowledge brokers.

emphasize the role played by social relations and social capital developing activities for the benefit of local community and other organizations that may make use of infrastructure (IV), try to maintain contacts with local government (VI) as well as to emphasize the role of family ties in business (VII). Obviously it is not necessary that current situation in the region is of the greatest significance for knowledge brokers that may be focused at non-local level when searching for valuable knowledge (III, VII). Regarding aspirations for making use of current events, trends in order to design possible future states of reality and organizational behaviour (b') it should be emphasized that investigated organizations try to adjust models of their operations to trends present in the world. They are aware of them thanks to global networks (II), ask fundamental questions about target model of activities (I), maintain active approach to the analysis of causes of possible failures thanks to leaders interested in considering the essence of their jobs (IV), try to deal with too high level of formalization (III), try to shape the ways in which the engagement of other organizations in cooperation take places avoiding interference of any kind (V), look for opportunities to realize new projects and thanks to it to go beyond specializations developed so far (VI), build new developmental propositions for organizations by comparing changes in parts of the world similar with regard to economy conditions (VII). Regarding openness to the environment and its co-creation (c'), it is worth noticing that generally all knowledge brokers under investigation can be considered as being really aware of the needs of organizations that cooperate with them. They may try not to resign from cooperation that does not meet their expectations hoping for the improvement of the situation in the future (I). It is possible that wanting to have their outstanding competencies proved they may be critically disposed to other organizations that are more profit oriented (III). Other organizations may try to help entrepreneurs to build formal basis for their future relations but at the same time paying much attention to all their ideas, including less definite plans (II). Other time they may aim at popularizing new ideas when conferences organized by knowledge brokers make it possible to discuss these ideas and sometimes to gain an insight into how they should be implemented (IV). Strengths of other organizations relate to abilities to think about their possible impact on others in a multidisciplinary way (VI), high mobilization that make it possible to both diagnose entrepreneurs' needs on daily basis and help in shaping broader view of them (VII) or fostering changes in the environment resulting from the fact that some entrepreneurs simply prefer talking to people who come from business than to others (V). Regarding willingness to introduce new practices and to abandon the old (d') it may be claimed that knowledge brokers are not afraid of changing relations with cooperating organizations and they can emphasize the need to introduce novelties when being asked directly about it. Consequently, they are willing to update their documents (I), change the schemes of activities (II) or try to differentiate their approaches to how work together with different partners (III). Sometimes limited resources may cause that all goals related to the introduction of novelties cannot be achieved (VI) or adaptations are rather small and made during short periods of time in a way that everyone should cope with (V). The interesting path of fostering changes appears to consist in showing local deficiencies in the light of solutions adopted in the world in such a way that knowledge brokers could become an initiator of changes in the the field of cooperation among scientists and business. At the same time it is important to remember that creating knowledge actually all knowledge brokers make use of standards thanks to which knowledge creation is energized and directed like e. g. maintaining the appropriate level of standardization of rendered services that are updated, focusing on different measures of their effectiveness or rejecting biased opinions among entreprenurs in region. The last aspect that is to be discussed here relates to the importance of

presence valuable resources in the environment as well as to the ways in which they can be transformed into regional benefits (e'). Although sometimes knowledge brokers can be more interested in the current economic situation on the macro level and possible country-wide advantages they maintain more or less their interest in the development of innovativeness of region. The presence of institutions that possess financial resources that are distributed next among partners is emphasized (I, II). Thanks to them it is possible to realize different projects, also these big ones supported by European Union. As a result, competencies can be acquired that are next transferred to cooperating organizations in region (III). It appears to be really positive when knowledge brokers emphasize the importance of holistic approach to the development combining economic, environmental and social aspects (IV). Their goals often are aimed at the development of entrepreneurship and innovativeness in region as well as they are eager to take part in initiatives important to local communities (VI, VII). Possible problems indicated by knowledge brokers relate to the willingness among their possible partners to reveal their knowledge or some difficulties sometimes emerging when knowledge that can be directly transformed into products and services is needed (V).

By descrbing the selected dimensions thanks to which it is possible to gain some insight as to how knowledge brokers operate it is necessary not to forget that based on literature and observations of the environment there are other dimensions to which attention may be paid. Hence, it would be possible to mention other aspects that may differentiate knowledge brokers that were investigated. For example, these aspects may be like the extent to which workers need to possess factual knowledge or be good at social relations. Other aspect is related to preferred time period of cooperation. It means that the more knowledge brokers need to use in knowledge co-creation, the longer cooperation is expected to last. Then different structures of knowledge retention can be used as well. Next aspect can be related to the approach to brokerage role. Although all knowledge brokers are far from trying to exploit its privileged position, they may try to actively support cooperating organizations that realise common projects or that try to build relation with others. However, due to differentiated reasons they also may focus only on monitoring the way relations are maintain. Finally, knowledge brokers generally consider their organizations as being quite effective, however, they match the antecedents of their effectiveness to the different aspects like being familiarized with many knowledge fields, capability of building teams or taking care of local community. Of course, all in all one can say they all are interconnected but as it turns out to be the fact that these aspects are emphasized from different point of view proves that knowledge brokers sometimes follow different logic of operations hidden behind sometimes different factors that are believed be the most important for effective cooperation. That is way it is also worth analysing dimensions like possible advantages derived from the cooperation perceived differently by the organization and by the broker. They may rely on different level of support from other regional and non-local institutions. In spite of the necessity to overcome similar problems related to knowledge transfer and creation they will endeavour to realise different visions and will be guided by leaders that may be focused on different areas of the reality.

Conclusions

The conducted research aimed at discussing the themes of analysis of activities undertaken by knowledge brokers in a way that enable comparisons among different knowledge brokers. In order to ensure that the selected dimensions can be distinguished in each case the author decided on following the path of analysis that emerged from studying literature related to knowledge creation, especially to the model of a knowledge-creating firm. Having chosen this

reference theory, next the author interpreted its components in order to make them meaningful in the light of processes in which knowledge brokers participate. Hence, the theoretical basis for comparisons described in this paper was formed. Apart from allowing the author to discuss important issues as to how activities of knowledge brokers may be improved conducted research should be useful when considering innovation policy that is to be implemented. Actually further analysis of described dimensions may allow to build some policy propositions with regard to possible to be distinguished types of models of activities of knowledge brokers based on their approaches to knowledge transfer, exploitation and creation, to building relations/networks as well as to regional development These are discussed by the author elsewhere [16]. Finally, it should be emphasiezed that it appears to be worth doing to search for other theoretical perspectives that could allow researchers to revisit the hitherto proposed classifications of activities of knowledge brokers. One interesting example of such attempts is the analysis conducted by L. Castro [17] who mobilized the theory of the practice to show how different types of brokering activities impact on strategy-making across knowledge and organizational boundaries. In order to be able to investigate activities of knowledge brokrers whose range is expetected to be extended new theoretical perspectives should be combined to make it possible to conduct more in-depth analysis. Because the described problems have interdisciplinary character they should go beyond the perspectives which are traditionally related to the management science.

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SWOT & GAP as Effective Tools of Strategic Diagnostics in Preparing Management Solutions for Youth NGOs

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Abstract – This article examines the practical application of two classic methods of strategic diagnostics (SWOT and GAP) in order to form the basis for making reasonable strategic decisions in the function of youth NGOs. The object of the study is the competitive and internal environment of youth organization BEST Lviv. Possibilities and advantages in managing the youth NGO that were provided by such diagnostics have been also identified.

Keywords – SWOT, GAP, strategic diagnostics, management solutions, NGO, BEST, Lviv.

Introduction

The implementation of the effective management of youth NGOs is complicated by the specific nature of their functioning, the misunderstanding of "players" and observers, that the functioning environment of these organizations is in fact competitive, the relative "weakening" of their regional leaders regarding to the need of development of applicable strategies. Therefore, the following realities are faced with youth NGOs: their regional development is not always stable and the "rules of the game" are not always well prescribed; despite the unprofitable nature of their functioning and the social orientation of their projects, market rules could also be applied to them.

Competitive relationships for youth NGOs are manifested in: 1) the selection of participants in social projects (which then go across from the category of service consumers to the implementers of these projects) [1]; 2) in choosing partners (employers, future sponsors, universities); 3) when forming the leading link of the NGO; 4) when forming the list of invited experts (coaches, mentors, consultants); 3) to the greater effect gained by the participants (better competitive qualities for future careers, for creating new directions of self-development, to acquire new skills of survival in society, to interact with others, in order cooperate with international institutions under the new rules); 4) in better financial support from the state, international grantors (received by those youth NGOs that have been able to show greater professionalism in project implementation, in solving social problems that are existing in the world, country, and region).

All of the above emphasizes the need for strategic management of NGOs, part of which is the diagnosis of their competitive environment. Such diagnostics should be the basis for making reasonable strategic decisions for the effective management of the development in NGOs. For practical validation of the results, will be used youth NGO "BEST Lviv" [2] and its regional competitors [3, 4], and will be taken classic diagnostic tools.

Main part of research

Strategic marketing diagnostics of the environment of the NGO "BEST Lviv" will be carried out by separate mutually complementary methods, which in our opinion will allow this organization to identify not only the obvious but also hidden strengths and weaknesses of its functioning, to have a better look at the opportunities and threats arising at its ways. This task

will be accomplished in this work by a combination of two diagnostic methods: SWOT (Table 1) and GAP (Table 2).

Table 1

SWOT environment diagnostics for preparation management solutions of NGO "BEST Lviv" *

	Strengths (S):	Weaknesses (W):
	* active cooperation with partners internationally * a very wide range of diverse skills that a student receives after being a member of youth NGO "BEST Lviv"; * the optimal structure of the organization, * established communication system within the organization; * protection against pressure from competitors, due to the more technical orientation of the function; * the presence of a large number of local groups (representatives of "BEST Lviv") across Europe	* great difference of goals for different projects (target segments) of the organization; * failure to attract additional financial resources to make the necessary changes; * incomplete use of internal capacity to implement the expansion strategy; * fragility and fluidity of human resources; * lack of well-defined market research approaches; * a large gap between the responsibilities assigned and the compliance of project managers; * incomplete system of mentoring and motivation; * loss of relevance in the projects of the organization; * the need to increase the loyalty of partner universities (regarding the working conditions of NGOs on their premises)
Opportunities (O): * constant change of concepts and ideas of social projects; * the possibility of developing a system of integrated communications with companies; o use of the international experience of NGOs in the development in amplification of strategies, improvement of project structure and organizational support for their implementation; * students' desire to learn modern technologies and management tools in the form of trainings	S-O field - use of new opportunities for organizing new international projects; - acquisition of new professional and personal skills necessary for self-development and growth of own career; - improving the strategy of cooperation with partner companies at the international level; - ensuring stable grant funding for the organization through stable cooperation with partners (employers and grantors, BEST International Offices)	W-O field - optimization of strategies will facilitate recruitment of new participants with fresh skills; - the advanced use of the latest communication technologies and motivational tools will allow all links of volunteers to better fulfil their responsibilities, create better projects, engage in promotion of NGO activities (as satisfied "clients"); - - Increasing trust in lower-level volunteers will increase teamwork efficiency
Threats (T): * increasing competitive pressure from existing competitors; * appearance of new competitors in selected niches; * continuous improvement of competitors' marketing moves; * better financial support of competitors; * increase in the cost of equipment required for projects; o increasing student requests for YNGO events; * iinsufficient state support for the activities of NGOs	S-T field - softening the requirements and improving the methods of selecting new members of the organization will increase their number; - establishing stable relationships with partners (employers) will improve the working conditions of the organization (better premises and equipment for work); - - research of today's needs of students will increase the relevance of the implemented projects	W-T field - reducing the motivation of the staff will reduce the percentage of their transition / appeal to competitors; - emphasis on social projects and communications will allow to find the best approach to the selection of personnel, to the analysis of change of their behaviour, to the development of new projects; - - creation of unique projects for different specialties will allow to take into account the interests of participants of different target segments

* results of authors' research and analysis of data from [2], [3], [4].

The main purpose of SWOT analysis was to identify the main problems of the organization and find productive and efficient ways of overcoming them. Management decisions can be formed: 1) or on the basis of actions deduced on a separate field of the SWOT matrix, taking into account the factors that created them (the main attention here should be given to the field S-O, its S and O); 2) or on the basis of combinations in actions formed on all 4 fields of the matrix, taking into account the relevant factors.

This type of analysis not only identifies the internal problems and external threats of an organization's functioning, but also assesses the current benefits of the Youth NGO and its enabling environment for development. However, this approach is not sufficient for a qualitative assessment of the level of identified threats and there is a need for more additional points for more detailed analysis.

In order to increase the effectiveness of work on threats and weaknesses of the organization's activities, it would be advisable to supplement the SWOT search for strategic gaps ("white spots") using the GAP method, which is highlighted in Table 2.

Table 2

GAP analysis for searching "white spots" in development problems' assessment of NGO "BEST Lviv" *

SWOT components**	Characterization of detected white spots (GAP)
Unused opportunities	- failure to take into account the wishes and basic interests of students; - neglecting all opportunities for interaction with partners.
Neglected Strengths	- incomplete use of knowledge and skills of students of technical specialties to form a system of communication integration with companies; - under-utilization of opportunities to exchange experience with Local Best Groups across Europe; - incomplete disclosure and harnessing the potential of economics students' potential to increase the socio-economic efficiency of individual projects; - Insufficient use of opportunities for the development of Youth NGOs with the participation of its graduates
Hidden Weaknesses	- insufficient attention was paid to measures to overcome low motivation of participants at all levels; - the selection criteria for mentors are not transparent; - the system of selection of new entrants and their transition to new levels requires improvement of the selection criteria; - the organization does not consider the full range of possible external sources of financing for individual projects
Neglected Threats	- Youth NGO underestimates the significant impact of market competitors with their new strategic moves; - Youth NGO does not consider Lviv regional administration and other local government agencies as an opportunity to obtain additional support for individual funding; - the organization does not consider bad conditions for project implementation as an obstacle (threat) to normal activities

* results of authors' research; ** SWOT components with possible disadvantages ("gaps")

The essence of the method lies in the study of the problem, which is manifested as a gap (from the English, Gap - hole, blank spot, omission), which arises during the implementation of the plan of change, between those indicators and results, which were planned, and what happened in reality. GAP analysis is based on two projections: 1) the target projection or the management (target) results established; 2) to change the current situation in the future (through

extrapolation). In the process of GAP-analysis it becomes clear what to expect in the future, if the management of the enterprise (top management) does not initiate change.

In this case, the GAP analysis was used as a flip of the standard perceptions of "S", "W", "O" and "T" perceptions. Due to this, opportunities ("O") are considered from the standpoint of the very opportunities that lie on the surface, “BEST Lviv” does not use, and therefore loses in strategic competition. Similarly, among the strengths ("S") it is shown which of our obvious strengths the organization does not even take into account, while greatly weakening its position.

Also, the organization under study has a number of hidden weaknesses ("W"), which are not very detrimental to the internal settlement of individual conflicts and the emergence of desirable options for interaction with the immediate environment. Neglected T also may sooner or later hit the NGO “BEST Lviv” quite hard, and bring it out of the stable development state that it has adhered to so far.

Thus, having analyzed the definitions in Table 2 the "white spots", taking into account the strategic ones set out in the SWOT analysis fields, there were identified the risks that could provoke a gap between the plans for change and their actual implementation. At the same time as the most probable were the following:

changes can take much longer than originally planned;

complex changes may not occur in the process of making changes that were not foreseen or analyzed before;

coordinating the activities of executives in the execution of individual tasks is not efficient enough and thoughtful, which leads to a number of organizational problems;

some critical threats may occur during the changes that will require the invention of the add-ons. capabilities and focus ext. resources to overcome them;

skills and abilities of new entrants involved in the organization may not be sufficient for the development and implementation of the planned projects (activities);

the level of preparation and understanding of the concept of change may not meet the pre-established requirements for the implementation of individual social projects (measures);

lack of interest from partners or lack of long-term partnership prospects may result from partner mismatch.

Conclusion

The mission of student NGOs (in particular, "BEST Lviv") is aimed at the personal development of students, their career support and assistance in self-realization at the international level through the organization of social projects of various subjects. Strategic diagnostics of the competitive environment, carried out in a combination of SWOT and GAP methods, allowed to identify clear and hidden strengths and weaknesses in its functioning, to have a better look at the opportunities and threats that arise in its path. All of the above should be taken into account when making their future strategic decisions.

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Shadow Economy Trends in Ukraine Economy and in the Industry of the Regions

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Abstract – The tendencies of shadow economy in Ukraine are analyzed. The level of shadow economy in Ukraine is predicted for 2019. The level of the industry shadow sector of the economy in the breakdown of regions for 2016-2017 is calculated. It was proposed to divide the regions of Ukraine into three groups: regions with permissible, critical and disastrous share of the shadow economy of industry.

Keywords – shadow economy, industry, financial and economic security, enterprises' loss method, cartogram, shadow profit.

Introduction

The shadow economy problem is an urgent in modern world. It threatens the financial and economic security of any country, region or industry. According to a study of Association of Chartered Certified Accountants (ACCA) on the assessment and forecast of global shadow economy development, Ukraine is in the top five countries with the largest shadow economy share (ranked third out of 28 countries with 46.12% of official GDP in 2017 compared to 45.96% in 2016) [1]. However, the Ministry of Development and Trade of Ukraine claims the opposite trend (decline to 32% in 2017 compared to 35% in 2016) [2]. Among other countries with high share of shadow economy, there are Azerbaijan (66.12%), Nigeria (47.4%), Russia (39.29%) and Sri Lanka (37.33%). On the contrary, the lowest shadow economy was observed in the United States – 7.69%, Japan – 9.89% and China – 10.17% [1].

1. Trends in the share change of shadow economy of Ukraine

There is no unified method to perform accurate estimation of the shadow economy level or fully take into account all the factors, able to affect it. Among the most relevant statistics based methods to determine the size of the shadow economy, applied in Ukraine, there are [2; 3]: "consumers' spending – retail turnover", financial, monetary, electronic, enterprises' loss. Each method covers a specific area of the national economy (with a correspondingly different share of the illegal sector). Therefore, only an integral indicator enables to perform the complex characteristic of such a phenomenon as the shadow economy.

All the methods used to assess the share of the shadow economy have shown it decreased in 2018 compared to the first half of 2017. Namely: the methods of "consumers' spending – retail turnover" and enterprises' loss shown a decrease in the shadow economy level by 3% each (up to 48% and 21% of official GDP respectively); according to the monetary method, the level of the shadow economy decreased by 2% (up to 23% of official GDP); the electronic method shown a 1% reduction in the shadow economy level (up to 27% of official GDP). Estimation according "consumer's spending – retail turnover" shows the highest shadow economy level in Ukraine. The lowest level is calculated by enterprises' loss method. Ukrainian shadow economy level dynamics over time in terms of isolated methods, is shown in Fig. 1.

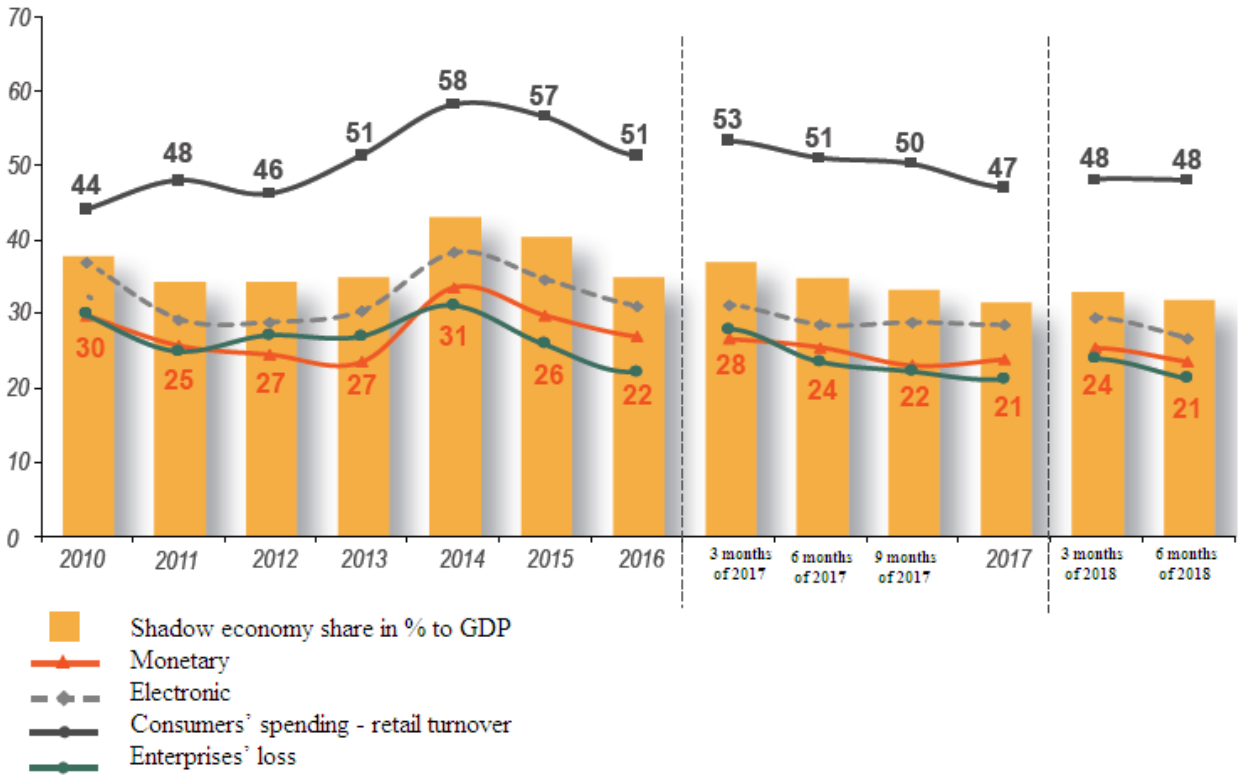


Figure 1. Ukrainian shadow economy share dynamics over time in terms of isolated methods, in % to official GDP [2]

Ukrainian shadow economy trend models, based on the performed regression analysis of 2010-2018 data, as well as the results of the forecast performed by authors for 2019 are presented in table. 1. Forecast results according to all methods show a decrease in the shadow economy level in Ukraine for 2019.

Table 1

Ukrainian shadow economy forecast results for 2019

Shadow economy estimation method	Trend equation	Determination coefficient value	Shadow economy level forecast, % of GDP
Consumers' spending – retail turnover	$y = -0,5747x^2 + 6,2301x + 37,048$	$R^2 = 0,629$ direct and strong dependency	42
Monetary	$y = -0,1147x^2 + 0,8805x + 25,786$	$R^2 = 0,083$ no dependency	23
Electronic	$y = -0,1277x^2 + 0,7104x + 32,381$	$R^2 = 0,1631$ direct and weak dependency	27
Enterprises' loss	$y = 30,917e^{-0,04x}$	$R^2 = 0,568$ direct and average dependency	21
Integral	$y = -0,2955x^2 + 2,4379x + 33,167$	$R^2 = 0,3763$ direct and weak dependency	28

Source: calculated by authors basing on [2].

It should be borne in mind that the Ukrainian shadow economy is peculiar because it is not completely informal. It is also a part of the legally registered economic entities activity. And also specifically is that the large industrial enterprises are mostly shadowed. This is due to several factors, such as it's very easy to register an individual entrepreneur in Ukraine. Individual entrepreneur can benefit of a simplified taxation, when only a single turnover tax is payed and accounting is simplified to keeping sales records [4]. Only a few multinational corporations are state-owned transparent enterprises. The rest companies are those, who use ties with the governmental authorities for the purpose of affording tax evasion and fraud.

2. Ukrainian industry shadow sector share estimation by regions

The trend towards a decrease in the shadow segment share in Ukraine in the first half of 2018 is stable for most of the main aggregated economic activities. Mining (by 9% compared to the corresponding period of 2017) and manufacturing (by 3%) were the leaders in rising transparency level of business among all industries in the first half of 2018. This was influenced by the range of factors. In mining industry these are:

–decrease of enterprises' losses (by 4.5x times; up to UAH 2.1 billion for the period of January-June 2018);

–decrease in the volume of profit received (by 1.4%, up to UAH 57.6 billion compared to January-June 2017);

–reduce of the number of enterprises that had losses (by 8.9% compared to the first half of 2017, up to 25.9% in 2018).

The decrease in the shadow economy share in manufacturing industry was caused by:

–a decrease in the amount of losses (by 1.1 times, up to UAH 30.8 billion in the first half of 2018 compared to the first half of 2017);

–an increase in profit received (by 1.7 times, up to UAH 78.2 billion for the same period).

To assess the level of shadow economy of the Ukrainian regions, basing on available statistics there are methods, offered by the Ministry of Economic Development and Trade of Ukraine. In our opinion, the most relevant method among them is enterprises' loss. This method is to determine the marginal minimum and maximum coefficients of the shadow economy as a GDP share, within which the shadow economy can be isolated.

When using the enterprise loss method, following assumptions are applied [2]:

–according to official statistics, all loss-making enterprises are profitable in fact, which is considered to be an overstatement of the shadow economy;

–the profitability level of unprofitable and profitable enterprises is equal in the analyzed period;

–the cost ratio of loss-making and profitable enterprises is identical to the ratio of the number of such enterprises.

Based on the data of State Statistics Service head and regional offices, we calculated the level of the industry shadow sector of the economy in the breakdown of regions for 2016-2017 (see Table 2).

The level of the industry shadow economy in Luhansk region exceeds 100% and is 417 and 320% in 2016-2017 respectively. This can be explained by the military conflict in the east of Ukraine, financial destabilization, growing panic of economic agents and increased administrative pressure. These data we also receive due to the inaccuracy and imperfection of the statistical information collection.

Table 2

The change of shadow sector share in industry of Ukraine in 2016-2017

Region of Ukraine	Gross value added at basic prices, mln. UAH		Conditional profit of unprofitable enterprises, mln. UAH		Shadow profit, mln. UAH.		Shadow economy share in industry Gross value added, %		Increase/ decrease of shadow economy share (+/-)
	2016	2017	2016	2017	2016	2017	2016	2017	
Volyn region	4743	5612	516.50	693.26	1363.65	1624.51	29	29	0
Rivne region	8186	9085	329.41	644.74	2923.08	2315.51	36	25	-11
Lviv region	15515	22751	1575.08	2201.76	4865.03	6091.58	31	27	-4
Ternopil region	3461	4194	207.74	373.47	665.25	5883.78	19	140	+121
Ivano-Frankivsk region	10612	12015	…	4403.94	…	9215.28	...	77	...
Transcarpathian region	3918	4873	356.87	391.12	1224.67	2039.79	31	42	+11
Chernivtsi region	1807	2302	494.14	262.02	1182.82	618.85	65	66	+1
Vinnytsia region	10950	14005	775.82	2048.45	1515.10	3033.57	14	22	+8
Khmelnytsky region	6828	8359	472.71	633.94	2464.10	2074.65	36	25	-11
Zhytomyr region	6522	8394	601.77	868.77	1927.44	2682.68	30	32	+2
Kiev region	17977	23996	2425.13	2667.10	7531.13	6035.25	42	25	-17
Cherkasy region	10504	12858	962.07	1430.41	3598.28	2919.42	34	23	-11
Kirovograd region	6398	8454	294.47	426.97	1110.68	909.65	17	11	-6
Mykolaiv region	8531	10315	638.63	741.96	8131.33	2946.10	95	29	-66
Odesa region	12294	14412	692.89	871.58	6230.32	5086.16	51	35	-16
Kherson region	3683	5203	404.26	486.49	1741.79	1433.37	47	28	-19
Chernihiv region	6833	7856	342.95	528.00	3560.24	899.93	52	11	-41
Sumy region	9401	10010	918.88	1132.81	2317.46	2909.96	25	29	+4
Poltava region	35086	49689	1296.55	4353.47	5913.74	7966.62	17	16	-1
Zaporizhzhia region	28168	34071	5439.90	7133.81	10355.04	8552.52	37	25	-12
Donetsk region	37548	48292	3809.83	5196.93	19500.21	37321.58	52	77	+25
Lugansk region	6390	8947	371.52	553.31	26660.45	28614.40	417	320	-97
Kharkiv region	28088	40988	2638.55	3400.44	9189.17	7962.69	33	19	-14
Dnipropetrovsk region	75818	91375	9302.92	21798.13	22704.80	43001.95	30	47	+17

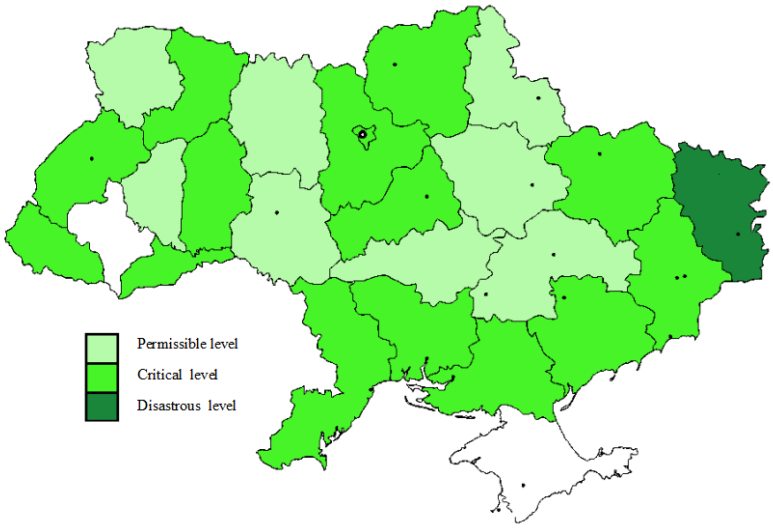
Source: calculated by authors basing on [5, 6]

In the Ternopil region, the level of the shadow economy increased by 121% in 2017 compared to 2016. It was coursed by the increase in the number of unprofitable enterprises in 2017 (from 26.6 to 31.3% of the total number of enterprises) and by the increase in the amount of loss (up to UAH 5510.3 million in 2017 comparing to UAH 457.5 million in 2016). This is due to the fact that in comparison with other regions of Ukraine, the Ternopil region has one of the lowest levels of innovation activity of industrial enterprises. Industrial enterprises development level depends on the innovations implementation. The insufficient financial condition of industrial enterprises (about half of them are unprofitable) does not satisfy their needs for modernization and replenishment of outdated fixed assets. The industry is dominated by backward technologies that lead to the consumption of large quantities of materials and energy resources.

Overall, excluding the above-mentioned regions, the share of the shadow economy in industry ranged from 11 to 77% in 2017. Kirovograd, Chernihiv, and Poltava regions have the

lowest share, with 11%, 11%, and 16% respectively. According to our calculations, the highest values are observed in Ivano-Frankivsk, Chernivtsi and Donetsk regions (77%, 77% and 66% respectively).

Considering that in scientific sources the threshold of 30% is considered a critical level of the shadow economy [7, p. 117; 8, p. 68; 9, p. 114; 10, p. 136], we propose to divide the regions of Ukraine into three groups: regions with permissible (0-30%), critical (31-100%) and disastrous (more than 100%) share of the shadow economy of industry. Ukraine regions mapping in terms of the shadow economy share in industry for 2016-2017 is shown in Fig. 2-3. According to this classification, the admissible level of shadow economy is observed in 15 regions in 2017 compared to 8 regions in 2016. Critical is stated in 7 regions in 2017 and in 14 regions in 2016. In 2017, Ternopil and Lugansk regions show the disastrous level of shadow economy, the same as Lugansk region in 2016.



Note: data for Ivano-Frankivsk region are not disclosed to ensure compliance with the requirements of the Law of Ukraine "On State Statistics" referring the confidentiality of statistical information.

Figure 2. Cartogram of Ukraine regions by industrial enterprises share in shadow economy in 2016

Source: elaborated by authors

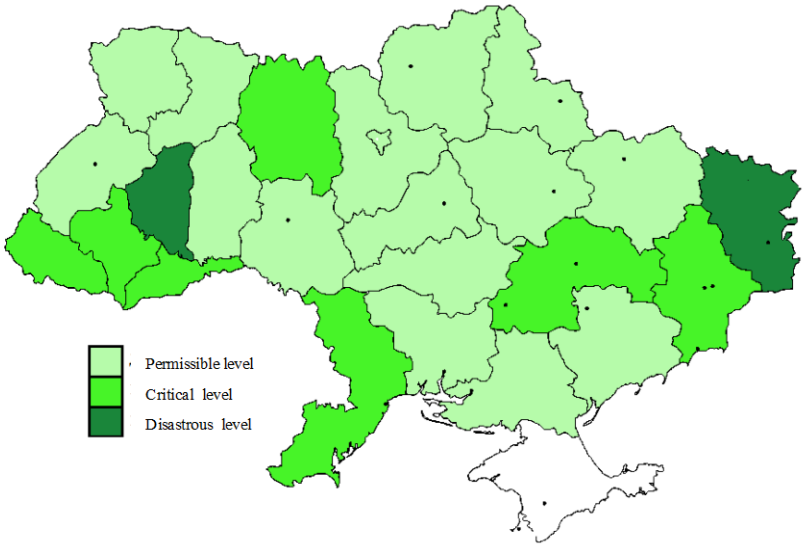


Figure 3. Cartogram of Ukraine regions by industrial enterprises share in shadow economy in 2017

Source: elaborated by authors

Conclusion

The activity of domestic industrial enterprises is getting more complicated each year. Every time, new and emerging threats emerge, which companies need to counteract to stabilize their own level of financial and economic security. One of the biggest threats is the shadow economy pressure. According to the calculations of the Ministry of Economic Development and Trade of Ukraine, the share of the shadow economy in Ukraine over the last 5 years stays in the range from 30 to 40%, and in industry – from 25 to 35%. The high share of shadow economy poses a threat to the financial and economic security of the region's industry and reduces its competitiveness.

The analysis of the shadow economy by the enterprises' loss method shows that despite the sufficient development of the methodological base, there are significant gaps in its implementation. In particular, the main one is the discrepancy between the results of the calculations. The method under consideration is imperfect if applied to Regional level with simultaneous absence and lack of reliability of information. Only the integral indicator of the shadow economy enables more accurate estimate.

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Research on Correlation between Nominal Exchange Rate of Ukrainian Hryvnia and Amount of Remittances under Impact of Volumes of Consumption in Ukraine

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Abstract – The purpose of this research is investigation of existence and character of correlation between nominal exchange rate of Ukrainian hryvnia and amount of net remittances under the impact of consumption in Ukraine by linear regression model, which includes lagged main components of balance of payments of Ukraine as variables in 1997-2017.

Keywords – exchange rate; remittances; balance of payments; linear regression model; consumption; marginal propensity to consume.

Introduction

The extreme fluctuations of the exchange rate of Ukrainian hryvnia during the last decade, especially as a result of floating exchange rate regime establishment affected Ukrainian economy significantly. At the same time dramatic rise of volumes of remittances of Ukrainian workers could restrain depreciation of Ukrainian currency, as it is investigated in foreign scientific sources. For instance, investigation of factors, which influence the real exchange rate of national currencies of Latin American countries, has revealed the significant impact of worker's remittances on its appreciation [1]. A result of other study of correlation between nominal exchange rate and factors of influence by usage of instrumental variables regression concluded, that in the fixed exchange rate regime, the volume of migrant remittances is higher than in the floating exchange rate regime [2]. The theoretical model of a small open economy with a fixed exchange rate regime confirms that a steady increase in the inflow of remittances will contribute to the appreciation of the national currency and will require maintaining the external and internal balance [3]. In a case of Philippines exchange rate shock of national currency revealed depreciation of Philippine peso tended to increase in volume of remittances [4]. Research on remittances impact on economic growth and development showed that remittances in developing countries are mostly used for consumption, what doesn't strengthen national currency [5]. Investigation of this correlation in the context of financial sphere showed, that for increase of efficiency of remittances for the economic growth the cost of sending remittance through official channels should be reduced [6]. Furthermore, increase in demand, as a result of increase in volume of remittances, requires depreciation of national currency, what reduces positive effects of a current account increase [3]. Some studies confirmed a substitution of bank loans by remittances, what engenders increase of households' investments in nontradable sector [7]. Also, remittances are an additional investment channel for developing countries, what promotes the economic growth [8]. In according to literature review the aim of research is to test a correlation between nominal exchange rate of Ukrainian hryvnia and volume of net remittances under the impact of volumes of consumption.

Research results

In according to the methodology of World Bank, personal remittances include personal transfers and compensation of employees. Personal transfers consist of all current transfers in cash or in kind made by resident households to or from nonresident households. Compensation of employees refers to the income of border, seasonal, and other short-term workers who are employed in an economy where they are not resident and of residents employed by nonresident

entities. The nominal exchange rate of Ukrainian hryvnia is calculated as year average rate on the basis of monthly average rates. As one can see, results of previous scientific studies are not applicable to Ukraine, as in floating exchange rate regime since 2015 remittances volume has been increasing; during the fixed exchange rate regime till 2015 Ukrainian hryvnia was depreciated (Fig. 1).

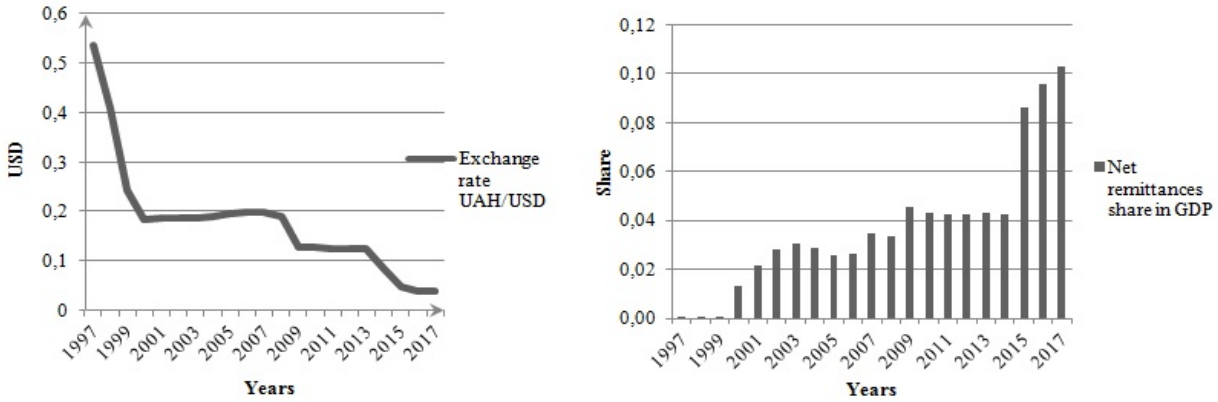

Figure 1. Dynamics of UAH/USD exchange rate in 1997-2017 and share of net remittances balance in GDP of Ukraine in 1997-2016 [9]

In order to investigate correlation between exchange rate of Ukrainian hryvnia and volume of remittances was suggested to use linear regression, which includes lagged components of balance of payments of Ukraine as variables. It is worth to mention, that exchange rate does not react immediately to rapid changes in balance of payments, as its final value forms during the year. Data on balance of payments of Ukraine in 1996-2017 was extracted from World Development Indicators Database [8]. To eliminate impact of possible multicollinearity, components were used as shares of GDP (Eq.1).

$$EXR_t = x_0 + x_1 REMIT_{t-1} + x_2 TRADE_{t-1} + x_3 FDI_{t-1} + x_4 PORTF_{t-1} \quad (1)$$

where EXR_t - nominal exchange rate UAH/USD in current period;
$REMIT_{t-1}$ -net remittances share in GDP of previous period;
$TRADE_{t-1}$ - net trade share in GDP of previous period;
FDI_{t-1} - net foreign direct investments in GDP of previous period;
$PORTF_{t-1}$ - net portfolio investments in GDP of previous period.

Thus, the hypothesis for received model is that an increase in volume of remittances leads to a depreciation of the Ukrainian hryvnia. Since an investigated period is unstable, the heteroskedasticity of the input data is possible, as there are rapid fluctuations in the balance of payments components, what can cause the statistical insignificance of most model parameters (Fig.2).

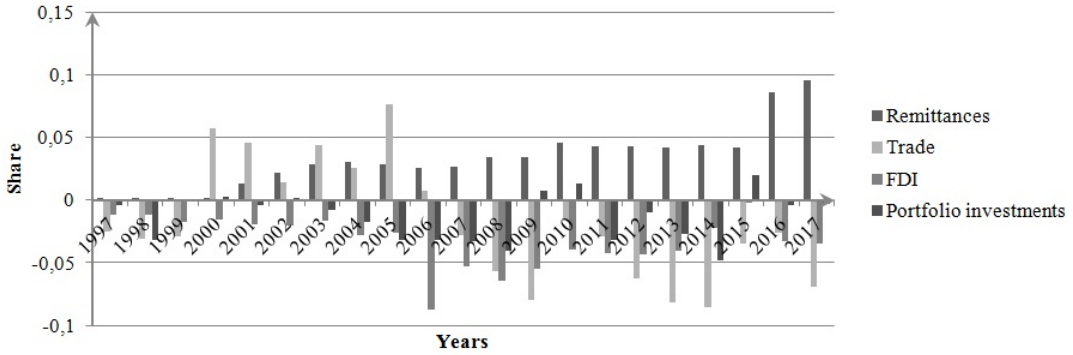

Figure 2. Dynamics of components of balance of payments of Ukraine as share of GDP in 1997-2017 [9]

Accordingly, the model should be tested with robust standard errors in order to obtain BLUE estimations. F-test demonstrated a significance of model at the level of 96%, the determination is 0.587, what indicates unpredictability of changes in variables, caused by dynamic changes in balance of payments of Ukraine during research period. Except this, hypothesis is confirmed, as correlation coefficient of remittances variable is negative and this variable is only statistical significant at the level of 99+% (Tab. 1).

Table 1

The results of linear regression model testing

Variables	Correlation coefficients	t-test	P>|t|	95% Confidence intervals	
				min	max
Net remittances (share of GDP)	-3.5339	-3.19	0.001	-5.8842	-1.1836
Net trade (share of GDP)	-0.2606	-0.63	0.557	-1.1375	0.6164
Net foreign direct investments (share of GDP)	0.5812	0.61	0.585	-1.4297	2.592
Net portfolio investments (share of GDP)	-0.7868	-0.75	0.480	-3.0199	1.4464
Constant	0.2968	4.8	0.000	0.1595	0.4342

Since only one parameter is statistically significant, it is appropriate to examine the model for autocorrelation and multicollinearity. So, in order to detect autocorrelation The Durbin-Watson statistics was used. Accordingly, the minimum and maximum values of the Durbin-Watson test for the 4 variables and 21 observations are 0.718 and 1.554, respectively. The calculated value of this statistics is 0.739, which is in the range between the minimum and maximum values, so it is impossible to determine the presence of autocorrelation. The presence of multicollinearity can be investigated by a correlation matrix (Tab. 2).

Table 2

A correlation matrix

Variables	EXR	REMIT	TRADE	FDI	PORTF
EXR	1	-	-	-	-
REMIT	-0.749	1	-	-	-
TRADE	0.2145	-0.4098	1	-	-
FDI	0.2202	-0.2589	0.2673	1	-
PORTF	-0.1424	0.053	0.1278	0.3934	1

The highest correlation coefficient is between nominal exchange rate and net remittances; coefficient of correlation between independent variables is not high, ecept a correlation between trade and remittances, and portfolio investments and FDI. To test a significance of correlation the VIF test is conducted, which is based on the estimation of the variance inflation factor. According to the test results, all model variables showed a variance inflation value below 10, and a tolerance index much higher than 0.1, confirming the absence of significant multicollinearity (Tab. 3).

Table 3

The VIF-test results

Variables	Indicators	
	VIF	1/VIF
Remittances balance (share of GDP)	1.29	0.75438
Trade balance (share of GDP)	1.26	0.776511
Net foreign direct investments (share of GDP)	1.33	0.7965
Net portfolio investments (share of GDP)	1.23	0.81117
Середнє значення показника	1.28	-

One of the causes of inverse correlation between exchange rate and remittances could be a usage of remittances for consumption, as it was investigated in previous studies. To test this assumption data on volumes of disposable income and consumption of households in Ukraine 2015-2017 was extracted from State Statistics Service of Ukraine database [10], what demonstrated greater volumes of consumption than volumes of disposable income (Fig.3).

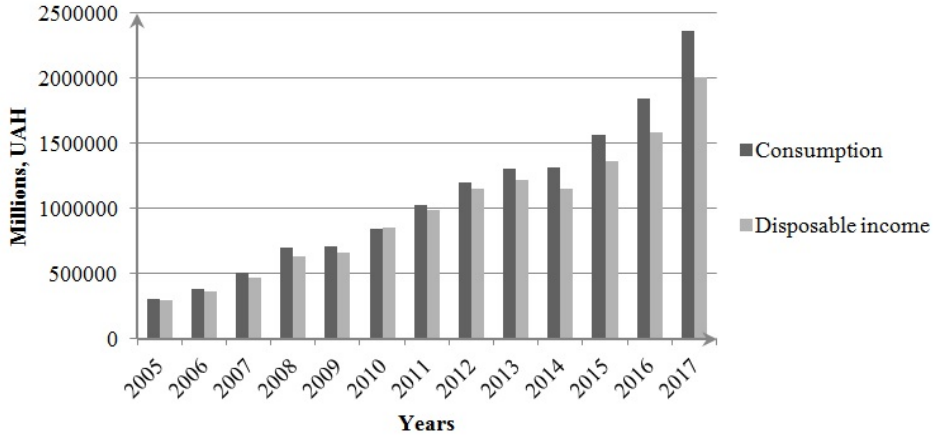

Figure 3. Volumes of consumption and disposable income in Ukraine in 2005-2017[10]

According to the methodology for calculating consumption and disposable income volumes, consumption includes the final expenses on goods, financial and government services and telecommunication services. Disposable income is the difference between the total income of the population excluding social transfers in kind and the amount of taxes paid and property income paid [10]. As a consequence, the amount of workers' remittances is not taken into account in calculating disposable income.In Keynesian model disposable income is used for consumption and savings, shares of which are determined by marginal propensity to consume and marginal propensity to save. In a case of Ukraine, the marginal propensity to consume is greater than 1, what could be engendered by credits, shadow economy, remittances and other sources of additional income. Finally, the volume of consumption reveals a share of income, which was not counted in general statistics. So, a difference between consumption and disposable income can be considered as a volume of additional consumption possible because of additional income. Thus, a real marginal propensity to consume can be described as the marginal propensity to consume corrected by a coefficient of additional consumption (Eq.2).

$$RMPC = MPC * E_a \Rightarrow \frac{\Delta C}{\Delta(Y_d+Y_a)} = \frac{\Delta C}{\Delta Y_d} * \frac{\Delta Y_d}{\Delta(Y_d+Y_a)}, \quad (2)$$

where $RMPC$ – real marginal propensity to consume;
MPC – marginal propensity to consume;
E_a – coefficient of additional consumption;
ΔC – change in consumption;
ΔY_d – change in disposable income;
$\Delta(Y_d+Y_a)$ – change in volume of disposable and additional income.

In a case of greater change in disposable income than change in volume of disposable and additional income, real marginal propensity to consume is less than marginal propensity to consume, as additional income create possibilities for saving. Accordingly, in Ukraine till 2014 numbers of these two indicators were almost equal (Fig.4).

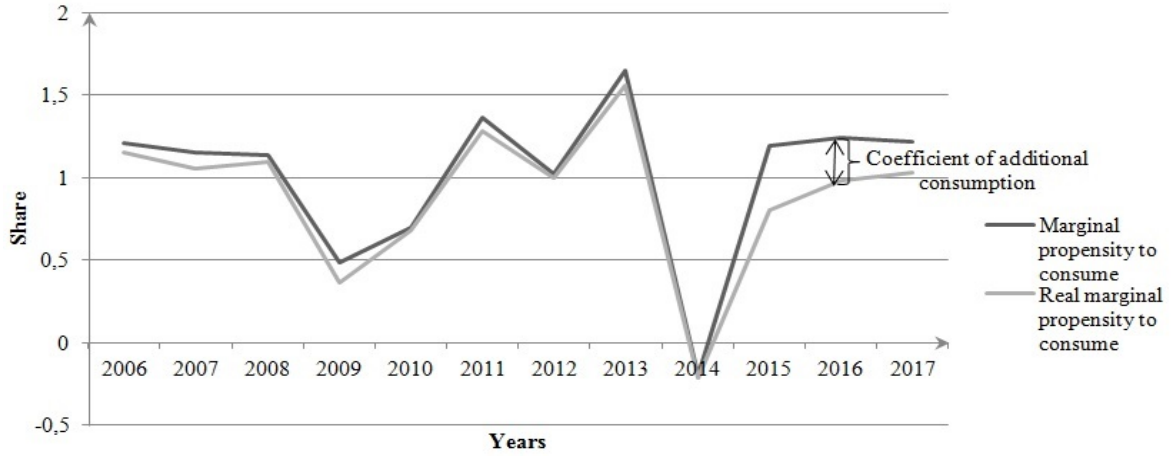

Figure 4. Marginal propensity to consume and real marginal propensity to consume in Ukraine in 2006-2017

Since 2015 a difference between MPC and RMPC has been increasing as volume of remittances raised. Nevertheless, exchange rate of Ukrainian hryvnia dramatically fell in the same year. During same period share of bank credits for households decreased, what confirms an assumption on substitution of bank loans with remittances (Fig. 5).

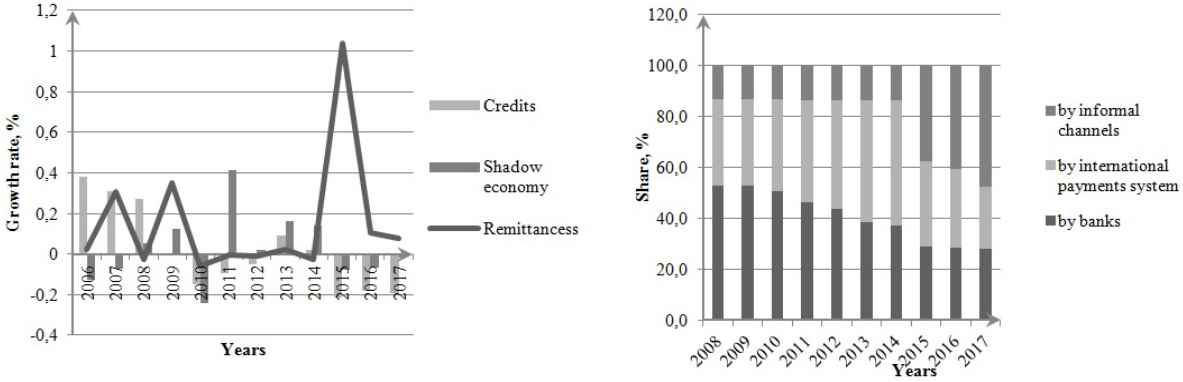

Figure 5. Growth rates of bank credits, shadow economy and remittances volumes as shares of GDP of Ukraine in 2006-2017

Except this, in 2014 a share of remittances sent by informal channels raised, what eliminates positive effects of current account improvement on Ukrainian hryvnia appreciation. Furthermore, remittances sent by informal channels could be in a form of goods, what complicates estimation of their volumes and influence on economy of Ukraine.

Conclusions

Results of conducted research showed inverse correlation between nominal exchange rate of Ukrainian hryvnia and volume of remittances. Moreover, volume of remittances influences exchange rate through volumes of consumption, as it was proved through analysis of disposable income of households of Ukraine. Nevertheless, developed regression model should be improved by inclusion of more factors, than influence exchange rate in order to strengthen correlation an adequacy of the model. The concept of real marginal propensity to consume demonstrates ability of households to save, and, possibly, to invest, in conditions of excessive consumption. Additionally, the concept of coefficient of additional consumption should be profoundly developed in a direction of investigation of other sources of additional income and improvement of calculation of their values, as limitations of data exist. For instance, incomplete statistics on

volume of remittances, great share of smuggling goods, what is not counted in consumption statistics. However, this concept could be used as a tool for prediction of exchange rate change as a result of change in additional income of households and for development of labor migration regulation for economic growth of Ukraine facilitation.

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8th INTERNATIONAL ACADEMIC CONFERENCE "MECHANICAL ENGINEERING, MATERIALS SCIENCE, TRANSPORT 2019" (MEMST-2019)

Study of the influence of the relationship of the components of exothermic mixture into FCAW-S on the melting indices

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Abstract –The effect of self-shieldedfiller wire core components (FCAW-S) on the fusion parameters, namely the addition of exothermic mixture (TM), the ratio of exothermic mixture components (CuO / Al), and the ratio of exothermic mixture oxidant to carbon content in the core composition(CuO/C) has been studied. It has been found that the optimum areas for the deposition rate (G_d), deposition factor (a_d) and spattering factor (ψ_s) are observed for the following values of the core components: TM = 25…39, CuO/C = 5..6, CuO/Al = 3…4.

Keywords: surfacing, FCAW-S, exothermic mixture, simplex- centroid design, deposition rate, deposition rate factor, spattering factor.

Introduction

Machines, their equipment and parts working under agriculture conditions are exposed to an intensive abrasive wear. Regarding the conditions and the intensity of the wear processes are integral part of the instruments lifetime and reliability as well as of the whole systems. Surfacing of parts is used to increase service life, manufacturability, and reduce production costs [1]. Throughout the diversity of reinforcement and restoration processes, the use of flux-cored wires (FCAW) has become widespread. When surfacing FCAW, as well as self-shielding flux-cored wires (FCAW-S), obtaining the welded metal of a given chemical composition, the required quality (in the content of non-metallic inclusions), as well as high technical and economic performance of the works (deposition rate and deposition rate factor) play an important role [2, 3, 4]. At the same time, the most important characteristics of deposition technologies are: deposition rate, deposition rate factor and the spattering factor [2-5].

During the melting of flux-cored wires, due to the lag of the melting of the core from the shell, a protrusion of the core is formed at the end of the flux-cored wire. This protrusion can be destroyed with the formation of large particles, which, when they enter the molten bath without having to melt, can cause exogenous inclusions [6]. In addition, the lag of the melting of the core from the shell, which causes deterioration of the welding performance and reduces the effectiveness of protection of weld metal from the air [2, 7]. One way to ensure uniformity of melting of the FCAW is to introduce into the mixture of the core of the exothermic mixture [4, 8, 9].

The most common exothermic systems are Fe_2O_3-Al, Fe_2O_3-Ti [10], while the CuO-Al system is of great interest [8], due to the greatest thermal effect, which makes it possible to exclude the possibility of the charge entering the weld bath when a smaller amount of exothermic is introduced, which makes it possible to achieve a higher degree of doping of weld metal. In addition, when using thermal mixtures of other systems, such as CuO, due to the reduction of the oxidant, the latter enters the metal, thereby doping it, which provides an even higher level of doping [8].

It is known that alloys with high carbon content are used for surfacing of abrasive and hydro-abrasive wear parts [12]. It is known that the recovery of copper oxide in exothermic mixtures can occur both aluminum and carbon. In this case, the degree and completeness of recovery by a particular reducing agent will depend on the ratio of components in the FCAW-S charge at constant other parameters. In the modern literature there is no data on the study of the

influence of the ratio of the components of the core of the powder wire, namely the components of the exothermic mixture and carbon. Thus, it is of considerable interest to study the effect of components of the exothermic mixture on the melting indices of the FCAW-S, to determine the optimal ratio of oxidant to the reducing agents of aluminum and carbon, as well as the optimal amount of exothermic mixture.

The objective of the paper. Determination of the nature of the effect and optimal values of the amount of exothermic mixture (TM), and the ratio of CuO/Al and CuO/C in the composition of FCAW-S filler on the qualitative indicators of its fusion using simplex-lattice design.

Materials and method

To investigate the effect of FCAW-S core composition on fusion rates, a standard three-factor simplex-centroid design has been selected. Experiments are being conducted to investigate the effect of filler components (amount of exothermic mixture) on the deposition rate (G_d), deposition rate factor (a_d) and spattering factor (ψ_s). The design in coded values is shown in table 1. To transmit from the simplex coordinate system to the natural values of the factors the following formulae are used:

$$(CuO/C) = 3 + 3 \cdot x_1 \quad (1)$$

$$(CuO/C) = 3 + 3 \cdot x_2 \quad (2)$$

$$(TM) = 25 + 40 \cdot x_3 \quad (3)$$

The design represented in natural values is also given in table 1.

Table 1.

Three-factor simplex-centroid experiment design

No.	Code values			Actual values		
	x_1	x_2	x_3	CuO/C	CuO/Al	TM, %
1	0	1	0	3,00	6,00	25
2	0,333	0,333	0,334	4,00	4,00	35
3	0,667	0,333	0	5,00	4,00	25
4	0	0,667	0,333	3,00	5,00	35
5	0,333	0	0,667	4,00	3,00	45
6	0,5	0,25	0,25	4,50	3,75	32,5
7	0,25	0,25	0,5	3,75	3,75	40
8	0,25	0,5	0,25	3,75	4,50	32,5
9	0,333	0,667	0	4,00	5,00	25

According to the experiment design matrix experimental wires have been produced the cores of which comprised components which composition is given in table 2.

FCAW-S with exothermic mixture with a diameter of 4 mm have been made for the research. As a slag-forming component, a slag material has been used: marble-fluorite-rutile. Deposition has been performed by single-pass rollers on 10x100x200mm S 235 J2G2 EN 10025-2 (St3ps) low-carbon steel plates using a welding machine with a power source ofconstant voltage. Wire Filling Ratio: 0.34-0.35.

The technological characteristics of the melting of cored wires G_d, α_d and ψ_s, were calculated according to the following equation are used:

$$G_d = \frac{m_d \cdot 3600}{t} \quad (4)$$

$$\alpha_d = \frac{G_d}{I_{asw}} \quad (5)$$

$$\psi_s = \frac{m_m - m_s}{m_m} \cdot 100\% \quad (6)$$

where m_m - the mass of molten electrode metal, g;
m_d - the mass of deposited metal, g;
m_s - the mass of spattering, g.

Table 2.

Composition of S-FCAW,%

The name of the component \ Experimental composition		1	2	3	4	5	6	7	8	9
Gas slag creating	Fluorspar GOST 4421-73	24	21	24	21	21	24	21	24	24
	Rutilovy concentrate GOST 22938-78									
	Calcium carbonate GOST 8252-79									
Alluring and deoxidizers	Titanium powder PTM TU 14-22-57-92	41	41	41	41	34	41	38	41	41
	Ferrosilicon FS-75 GOST 1415-78									
	Ferromanganese FMN-88A GOST 4755-91									
	Metal Chrome X99 GOST 5905-79									
	Ferovanadiy FVd-50 GOST 27130-94									
Graphite is silver		5,6	5,8	3,45	7,6	7,1	4,9	7	5,8	4,3
Oxide of copper powder-like GOST 16539 79		16,7	25	17,25	22,8	28,5	21,8	26	21,8	17,3
Aluminum powder PA1 GOST 6058-73		2,8	5,8	4,3	4,6	9,5	5,8	7	4,9	3,5
Iron powder PZhR-1 GOST 9849-86		9,9	3,1	10	3	0	2,5	1	2,5	10

Results and Discussion

Results of the experiment and calculations (G_d^s ,α_d^s, ψ_s^s) are given in table 3.

The results of the analysis of the influence of factors on the deposition rate (G_d), deposition rate factor (α_d) and spattering factor (ψ_s) are given in Table 3.

Table 3.

Results of research

No.	Welding current I_{awc}, Amp	Deposition rate, g/ h		Deposition rate factor, g/Amp•h		Spattering factor, %	
		Experimental, G_d^e	Calculated, G_d^s	Experimental, α_d^e	Calculated, α_d^s	Experimental, ψ_s^e	Calculated, ψ_s^e
1	353,48	4,192	4,182	11,860	11,636	14,35	14,35
2	356,9	4,686	4,765	13,130	12,210	9,90	9,90
3	357,3	4,655	4,631	13,027	12,938	14,95	14,95
4	372,22	4,590	4,604	12,331	12,643	13,62	13,62
5	370,8	3,972	3,989	10,711	11,022	20,84	20,84
6	380,58	4,806	4,847	12,628	12,875	9,74	9,74
7	407,47	4,769	4,564	11,704	11,751	10,75	10,75
8	395,85	4,654	4,706	11,756	12,000	10,85	10,85
9	395,7	4,228	4,214	10,685	10,958	20,27	20,27
10	372,6	3,844	3,893	10,317	10,116	17,94	17,38

Analysis of the design data obtained using Statistica (StatSoft) system [11]. The results of the model significance obtained using Statistica program for three fusion indices are shown in Fig. 1.

Overall Fit of Model; Var.: Gн, kg/h (CuO-C-Al-%TM)
3 Factor mixture design; Mixture total=1,, 10 Runs

Source	SS	df	MS	F	p
Model	1,023849	6	0,170641	8,966086	0,049807
Total Error	0,057096	3	0,019032		
Total Adjusted	1,080944	9	0,120105		

a)

Overall Fit of Model; Var.: αн, g/Ah (CuO-C-Al-%TM)
3 Factor mixture design; Mixture total=1,, 10 Runs

Source	SS	df	MS	F	p
Model	8,448603	6	1,408100	4,166067	0,134486
Total Error	1,013978	3	0,337993		
Total Adjusted	9,462581	9	1,051398		

b)

Overall Fit of Model; Var.: ψp, % (CuO-C-Al-%TM - Показа
3 Factor mixture design; Mixture total=1,, 10 Runs

Source	SS	df	MS	F	p
Model	144,6512	6	24,10853	16,44746	0,021394
Total Error	4,3974	3	1,46579		
Total Adjusted	149,0486	9	16,56095		

c)

Fig.1. Results of calculating the significance of the model by the residual sum of the squares: a) deposition rate (G_d); b) deposition rate factor (α_d); c) spattering factor (ψ_s).

Statistically significant effects are observed when p <0.05 is a Student's test. Analyzing the data obtained, we can conclude that the models obtained are significant.

$$G_d = 5{,}89299 \cdot x_1 + 4{,}20769 \cdot x_2 + 3{,}17881 \cdot x_3 - 3{,}06163 \cdot x_1 \cdot x_2 - 0{,}34053 \cdot x_1 \cdot x_3 + \\ + 2{,}97135 \cdot x_2 \cdot x_3 + 10{,}67538 \cdot x_1 \cdot x_2 \cdot x_3 \quad (7)$$

$$\alpha_d = 19{,}4971 \cdot x_1 + 11{,}91117 \cdot x_2 + 9{,}1192 \cdot x_3 - 17{,}9461 \cdot x_1 \cdot x_2 + 8{,}5066 \cdot x_1 \cdot x_3 \\ + 5{,}1104 \cdot x_2 \cdot x_3 + 36{,}6739 \cdot x_1 \cdot x_2 \cdot x_3 \quad (8)$$

$$\psi_s = 0{,}2097 \cdot x_1 + 14{,}487 \cdot x_2 + 22 \cdot x_3 - 46{,}4368 \cdot x_1 \cdot x_2 + 28{,}036 \cdot x_1 \cdot x_3 - 16{,}2571 \cdot x_2 \cdot x_3 \\ - 237{,}7167 \cdot x_1 \cdot x_2 \cdot x_3 \quad (9)$$

When turning the simplex coordinate system to the natural values of the factors we get the following equation:

$$G_d = -15{,}105 + 3{,}888 \cdot (\mathrm{CuO/C}) + 2{,}1714 \cdot (\mathrm{CuO/Al}) + 0{,}1508 \cdot (\mathrm{TM}) \\ - 0{,}7922 \cdot (\mathrm{CuO/C}) \cdot (\mathrm{CuO/Al}) - 0{,}0601 \cdot (\mathrm{CuO/C}) \cdot (\mathrm{TM}) \quad (10) \\ - 0{,}029 \cdot (\mathrm{CuO/Al}) \cdot (\mathrm{TM}) + 0{,}024 \cdot (\mathrm{CuO/C}) \cdot (\mathrm{CuO/Al}) \cdot (\mathrm{TM})$$

$$\alpha_d = -37{,}1 + 9{,}496 \cdot (\mathrm{CuO/C}) + 4{,}814 \cdot (\mathrm{CuO/Al}) - 0{,}162 \cdot (\mathrm{TM}) \\ - 1{,}327 \cdot (\mathrm{CuO/C}) \cdot (\mathrm{CuO/Al}) + 0{,}0137 \cdot (\mathrm{CuO/C}) \cdot (\mathrm{TM}) + 0{,}1219 \cdot (\mathrm{CuO/Al}) \cdot (\mathrm{TM}) \quad (11)$$

$$\psi_s = 221{,}32 - 89{,}23 \cdot (\mathrm{CuO/C}) - 72{,}17 \cdot (\mathrm{CuO/Al}) - 7{,}58 \cdot (\mathrm{TM}) + 27{,}17 \cdot (\mathrm{CuO/C}) \cdot (\mathrm{CuO/Al}) \\ + 2{,}953 \cdot (\mathrm{CuO/C}) \cdot (\mathrm{TM}) + 2{,}461 \cdot (\mathrm{CuO/Al}) \cdot (\mathrm{TM}) - 0{,}88 \cdot (\mathrm{CuO/C}) \cdot (\mathrm{CuO/Al}) \cdot (\mathrm{TM}) \quad (12)$$

The resulting response surface simulations and contour plots are shown in Fig.2.

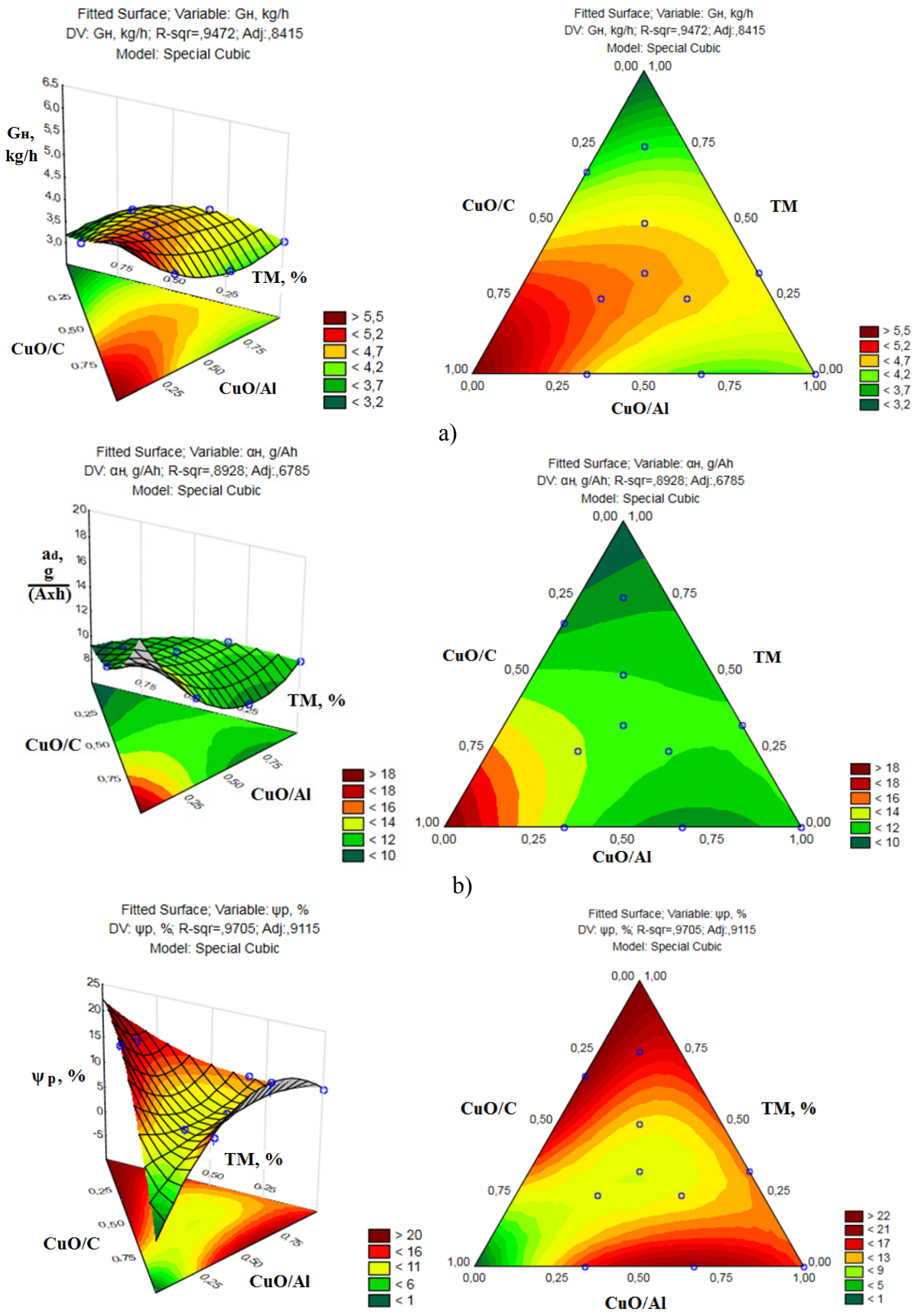

Fig.2. Response surface and contour plot depending on exothermic mixture (TM) content, ratios (CuO/C) and (CuO/Al) for melting ratios: a) deposition rate (G_d); b) deposition rate factor(α_d); c) spattering factor (ψ_s).

The highest values of deposition rate according to the results of the study depending on the response surfaces and contour plot (see Fig. 2 a) of the mathematical model (Eq. 10)

correspond to the minimum amount of exothermic mixture (0 ... 0.30, respectively) of the total fraction of the FCAW-S core, high ratios of CuO/C = 5… 6 (code values 0.6… 1), and low ratio CuO/Al = 3… 4 (code values 0… 0.25). That is, in order to achieve high deposition rates in the composition of the flux wire, the amount of aluminum over the percentage of silver (carbon) graphite must prevail.

For deposition rate factor (α_d), the obtained dependencies are retained. According to the response surfaces and the contour plot obtained (Fig. 2 b), as well as the model obtained in natural equation (Eq. 11), the following values of the variable parameters correspond to the highest values of the deposition rate factor (α_d): TM = 25… 39 (code values 0… 0.34); CuO/C = 5…6 (code values 0.6…1); CuO / Al = 3… 4 (code values 0… 0.33).

The analysis of the response surfaces obtained (Fig. 2c) shows that the spattering loss factor (ψ_s) decreases with increasing of Cu/C ratio, i.e. decrease in carbon (silver graphite) in the FCAW-S core composition, and decrease in CuO/Al ratio. Technologically acceptable indicators are achieved at the following values: TM = 25… 45 (code values 0… 0.5); CuO/C = 4.5… 6 (code values 0.5… 1); CuO/Al = 3… 4.5 (code values 0… 0.5)

The interpretation diagram of the imposition of certain areas of optimal values (Fig. 3) provides an opportunity to determine the optimal limit of the complex effect of the factors under the study.

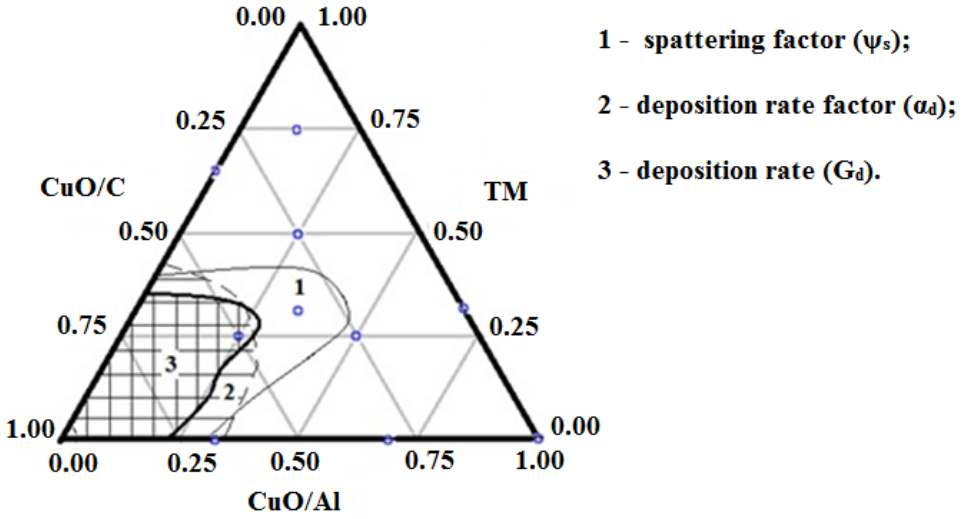

Fig.3. Interpretation diagram of optimal value areas

It has been found that the optimum areas for the deposition effectiveness (G_d), deposition rate factor (a_d) and spattering factor (ψ_s) are observed for the following values of the core components: TM = 25…39, CuO/C = 5..6, CuO/Al = 4.

Conclusion

As a result of the studies performed, the nature of the effect of the exothermic mixture and the ratios of the exothermic mixture (CuO) oxidant to the exothermic mixture reducing agent (Al), i.e. CuO/Al, and the exothermic oxidizer (CuO) oxidant to the oxidizing agent to carbon (C) have been determined.

Mathematical models have been obtained and response surfaces for the deposition rate (G_d) indices, deposition factor (α_d), and spattering factor (ψ_s) depending on the content of the components of the exothermic mixture and the carbon core of the flux wire have been built.

The greatest effect on the welding and process characteristics of FCAW-S has the ratio of components of CuO/Al exothermic mixture.

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The Stabilization of the Drop Formation Process in the Vortex Granulator

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Abstract – The necessity to use multizone workspace of the vortex granulator (including a zone of the drop formation stabilization) with various hydrodynamic features of the flow motion is proved in the article. New construction of the vortex granulator with the central zone of the drops stabilization with ascending gas flow is represented. The technological calculation algorithm regarding the section of the drop formation stabilization is given.

Keywords – vortex granulator, drop, stabilization, algorithm of calculation

Introduction

Among a large number of hardware design variants for granulators with a fluidized bed [1,2], one should distinguish granulators with a directed vortex layer of granules [3–5]. In such devices, due to the high relative velocity of the flows and high specific productivity, the granules formation process proceeds with the possibility to control the physical and chemical properties of granules in time [6]. Vortex granulators have been already tested in units for the production of porous ammonium nitrate by humidification method followed by heat treatment [7–9]. The application of a liquid film to the seeding agent's surface during the operation of the vortex granulator as part of the above unit has been technologically and constructively worked out. However, the direct formation of the drop in a vortex flow is combined with difficulties caused by the peripheral and radial velocity of the high-intensive gas flow.

In order to solve this problem, a separate zone of formation and stabilization of the drop shape should be distinguished in the vortex granulator's workspace, where these processes will take place in a laminar mode in a gas flow without a gradient of circumferential and radial velocities. Having adapted the cooling and crystallization method of granules in granulation towers in the ascending motion of cooling air [10, 11] for a vortex granulator, it is possible to maintain the main advantages of the granule formation method in a vortex gas flow in combination with a reliable method of drop formation stabilization process. This article describes the new organization of the flow motion, the new design of the vortex granulator, and the theoretical basis to calculate the stabilization section in the vortex granulator.

Theoretical Basics

In order to reduce the influence of external forces on the shape of the drop and maximum to prevent it from deformation, a new granulation method and new design of a two-zone granulator were proposed (Fig. 1) [12].

The granulator has a main vertical conical case 1 with a flat cover 2 and an additional case 3, which is concentrically centred to case 1 and is rigidly attached to it with a conical cover 4, consisting of the upper cylindrical part 5 and the lower conical part 6. The additional case 3 forms together with the main vertical case 1 interannular space 7, which is limited by the wall of the main vertical case 1 and the wall of the lower conical part 6 of the additional case 3. The pipe 8 is used to feed the heat transfer agent in the first zone of its contact with granules, the exhaust heat transfer agent is moved from the first contact zone through the pipe 9, located in the conical cover 4 on one axis with the device. The device also includes a pipe 10 to feed the liquid source

material with the spraying node 11, located coaxially with the additional case 3. The output of the granules after the primary contact with the heat transfer agent's flow in the interannular space 7 is carried out by the pipe 12, located in the lower section of the lower conical part 6 in the additional case 3. In order to feed the heat transfer agent to the second contact zone with the granules pipe 13, tangentially located at the bottom of the main vertical case 1, is used. The output of the exhaust heat transfer agent from the secondary contact zone occurs through the pipes 14, located coaxially with the main vertical case 1. The removal of the granules of the finished product occurs through the discharge pipe 15, located at the top of the main vertical case 1.

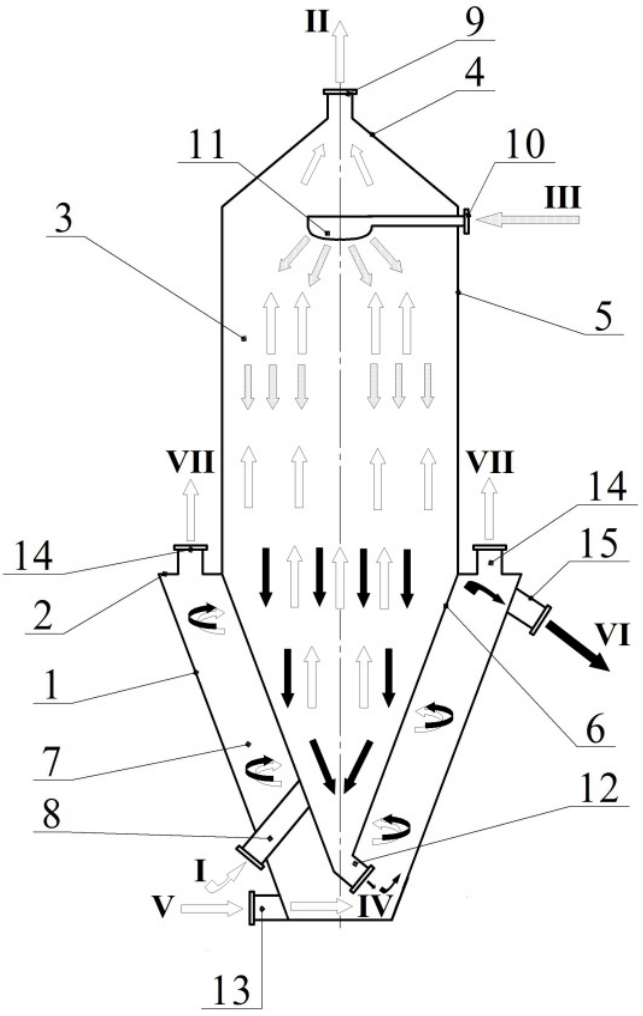

Fig.1. Vortex granulator with two granulation zones

The heat transfer agent (I), which in its ascending motion consequenctly passes the lower cocnical part and upper cylindrical part 5 of the additional case 3 , moving towards the material, is fed to the granulator through the pipe 8 to the lower conical part 6 of the additional case 3, and is output through the pipe 9 in the conical cover 4 (II). At the same time, the melt (III) is fed to the ascending flow of the heat transfer agent through the pipe 10 to the spraying node 11. The melt jet flowing from the spraying node 11 breaks down into separate spherical drops that move counter-current to the heat transfer agent's flow. During the motion, influenced by the heat transfer agent's ascending flow, drops in laminar hydrodynamic mode consistently pass the upper cylindrical part 5 and the lower conical part 6 of the additional case 3. During this motion, starting from the drops' surface, they are gradually cooled and the melt is crystallized. The granules with the formed solid surface layer are output from the lower conical part 6 of the

additional case 3 (IV) and reach the interannular space 7 between the main vertical case 1 and the additional case 3. At the same time, a the heat transfer agent's flow is input to interannular space 7 through its lower cross-section 13 for the secondary contact with the granules (V).

Due to the tangential inflow of the heat transfer agent to the interannular space 7, it is twisted around the vertical axis in the device and moves spirally. The vortex axisymmetrical stream of the heat transfer agent moves upwards through the interannular space 7, takes the granules in rotational motion in a turbulent hydrodynamic mode, creating a vortex weighted layer of granules in the interannular space 7. Granules, which are captured by the vortex axisymmetrical stream of the heat transfer agent, during the secondary contact with it, gradually reduce their mass due to layer-by-layer crystallization and their density reduction while keeping the volume and move to the upper cross-section of the interannular space 7; in this case, in the granule's space the cooling and crystallization process of the melt is completed and in the upper cross-section of the interannular space 7 granules have the necessary structure for its further use as a commodity product. These granules are output from the device through the pipe 15 in the main vertical case 1 (VI). The exhaust heat transfer agent after secondary contact with the granules in the interannular space 7 is discharged through the pipes 14 in the flat cover 2 of the main vertical case 1 (VII).

The complete crystalline structure of the granule is formed due to the increase of the heat and mass transfer processes intensity with the heat transfer agent's flow; due to the action of the heat transfer agent's vortex flow in the interannular space of the device, the velocity of phase motion increases, which contributes to the rapid removal of heat and moisture from the granules' surface, resulting in a shorter residence time of the granules in the device. It enables to reduce such destabilizing factors as the friction on the inner surface of the device and between the surfaces.

Results and Discussion

The purpose of the calculation is to find the initial velocity of the solution (melt) outflow from the disperser basket, the optimal diameter of the drops, the ascending gas flow velocity, the irrigation area of the central zone in the vortex granulator with the ascending gas flow, and the dependence of the way, which the drop passed, on time.

Leaving the disperser, the drop moves dynamically (with acceleration), therefore, it is necessary to determine the maximum velocity at which the drops are irreversibly deformed and crushed. During the motion, the surface tension increases, the outer layers of the drop are crystallized and the granule does not practically perceive the deformations. The time and permissible motion velocity of the contacting spaces are the key parameters to identify the path of the granule. The most accurate calculation and the optimal choice of the constructive parameters make the base to determine the height of the central zone in the vortex granulator with the ascending gas flow.

The Weber criterion, which determines the hydrodynamic conditions for drop crushing is used for the calculation [13]:

$$We = \frac{W_{cr}^2 \cdot \rho_g \cdot d_{dr}^{cr}}{\sigma_s}, \qquad (1)$$

where W_{cr} – the maximum acceptable (critical) velocity of the drop, ρ_g – density of the ascending gas flow, d_{dr}^{cr} – maximum (critical) diameter of the stable (undeformed) drop, σ_s – dynamic viscosity of the solution (melt).

Drops are moving constrainedly in the granulation tower, forming the reduced pressure areas in the tail. When these areas are broken, there are vortices, which influence the neighbouring drops.

Let us determine the maximum possible velocity of drops and their critical size, based on the forces equilibrium, influencing it during the fall.

$$m_{dr} \cdot g = F_r; \quad (2)$$

$$m_{dr} \cdot g = \zeta \cdot \frac{\pi \cdot (d_{dr}^{cr})^2}{4} \cdot \rho_g \cdot \frac{W_{rel}^2}{2}, \quad (3)$$

$$W_{rel} = \sqrt{\frac{1,333 \cdot \rho_s \cdot d_{dr}^{cr} \cdot g}{\zeta \cdot \rho_g}}, \quad (4)$$

where m_{dr} – the mass of the drop, ζ – drag force coefficient, W_{rel} – relative velocity of the drop motion (in relation to the ascending gas flow), ρ_s – density of the solution (melt)

Given the condition for drops crushing (1), we obtain the system:

$$\begin{cases} W_{rel} = \sqrt{\frac{1,333 \cdot \rho_s \cdot d_{dr}^{cr} \cdot g}{\zeta \cdot \rho_g}} \\ W_{кр} = \sqrt{\frac{\sigma_s \cdot We}{d_{dr}^{cr} \cdot \rho_g}} \end{cases}; \quad (5)$$

Levelling the maximum accessible velocity of the drop as relating to the gas space with the critical velocity, and solving the system, we will obtain:

$$d_{dr}^{cr} = \sqrt{\frac{We \cdot \sigma \cdot \zeta}{1,333 \cdot \rho_s \cdot g}}. \quad (6)$$

The Weber criterion values are defined by the features of the drop flow, the gas flow mode, and the physicochemical properties of the flows [13].

Based on [14] the distance between horizontally and vertically moving drops (granules) must be $3d_{dr}^{cr}$ and $11d_{dr}^{cr}$ respectively. Then the average density of the solution or melt (analogue of bulk density for bulk materials) in the space of the vortex granulator's central zone with ascending gas flow

$$\rho_{av} = \rho_s \cdot \frac{\upsilon_1}{\upsilon_2}, \quad (7)$$

where $\upsilon_1 = \frac{\pi \cdot (d_{dr}^{cr})^3}{6}$ – volume, occupied by one drop, $\upsilon_2 = \pi\left(3 \cdot d_{dr}^{cr}\right)^2 \cdot 11 \cdot d_{dr}^{cr}$ – the necessary volume of the granulator's workspace, occupied by the drop according to the condition of the recommended distance between drops.

The volumetric flow rate of the solution (melt) in the workspace of the central zone in the vortex granulator is:

$$V_s = \frac{G}{\rho_{av}}, \quad (8)$$

where G - the mass rate of the solution (melt)

The required throughput of the central zone in the vortex granulator

$$V_{centr} = V_g + V_s, \quad (9)$$

where V_g - volumetric gas flow rate, which is fed into the central zone of the vortex granulator

The velocity obtained by formula (4) is the sum of the drop's (granule) velocity relative to the walls of the central zone in the vortex granulator W_{dr} and the ascending gas flow velocity W_g

$$W_{dr} + W_g = W_{rel} = const; \qquad (10)$$

Thus, increasing the gas space velocity, it is necessary to reduce the velocity of the drops (granules), and vice versa. Given the possibility of the device to work at the maximum accessible mode – the suspension mode of granules, the minimum cross-sectional area of the central zone in the vortex granulator is calculated:

$$A_{\min} = \frac{V_{centr}}{W_{rel}}. \qquad (11)$$

The minimum internal diameter of the central zone in the vortex granulator

$$D_{\min} = \sqrt{\frac{4 \cdot A_{\min}}{\pi}}; \qquad (12)$$

The central zone diameter of the vortex granulator is absolutely taken according to the calculation of the radial outgoing of the drops.

Let us consider the equation regarding the motion dynamics of a drop. Neglecting the buoyancy force (since the air density is insignificant compared to the density of the solution or melt), we obtain the expression:

$$\begin{cases} m\dfrac{d^2 s}{d\tau^2} = m_{dr} \cdot g - F_{r1} \\ m\dfrac{d^2 r}{d\tau^2} = -F_{r2} \end{cases}; \qquad (13)$$

where $F_{r1} = \zeta \dfrac{\pi \cdot (d_{dr}^{cr})^2}{4} \cdot \dfrac{\rho\left(\dfrac{ds}{d\tau} - W_z\right)^2}{2}$ – vertical component of the motion resistance force, $F_{r2} = \zeta \dfrac{\pi \cdot (d_{dr}^{cr})^2}{4} \cdot \dfrac{\rho \cdot W_r^2}{2}$ – motion resistance force in the radial direction, ds – the elementary motion of the drop vertically relative to the wall of the device, dr - the elementary motion of the drop in the radial direction of the device (Fig. 2a).

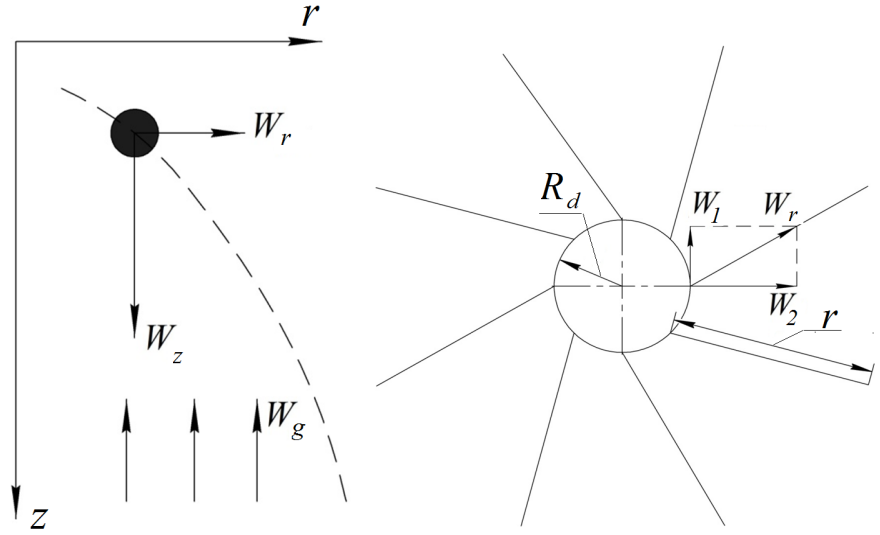

Fig. 2. Scheme of the drops' motion: a – in the central zone in the vortex granulator with the ascending gas flow; b – in the radial direction

The radial velocity of the drop's motion W_r is identified according to the disperser's rotation velocity (in terms of its rotation) W_1 and velocity of the solution (melt) pressure W_2

$$W_r = \sqrt{W_1^2 + W_2^2}, \qquad (14)$$

$$W_1 = \frac{\pi \cdot n}{30} \cdot R_d, \qquad (15)$$

$$W_2 = 0,95\sqrt{2 \cdot g \cdot h}, \qquad (16)$$

where n – number of the disperser's rotations, R_d – radius of the disperser, h – level of the solution (melt) in the disperser.

Substituting the received value for radial velocity to the second system (13), we calculate the extreme radial position and time at which the drop will reach it:

$$a_r = \frac{d^2 r}{d\tau^2} = -\zeta \cdot \frac{\pi \cdot (d_{dr}^{cr})^2}{4 \cdot m_{dr}} \cdot \frac{\rho \cdot W_r^2}{2}. \qquad (17)$$

Time at which the drop will cover the distance from the outgoing point to the extreme position:

$$\tau = \frac{W_r}{a_r}. \qquad (18)$$

The distance will be:

$$r = \frac{a_r \cdot \tau^2}{2}. \qquad (19)$$

Thus, the irrigation radius will be defined as the sum of the disperser's radius and the radius of the maximum radial distance, passed by the drop (Fig. 2b):

$$R_{ir} = R_d + r. \qquad 20)$$

The irrigation area:

$$A_{ir} = \pi \cdot R_{ir}^2; \qquad (21)$$

In order to determine the dependence of the passed distance by drops on time at different velocities of the ascending gas flow, let us consider the first equation of system (13).

This equation is solved using the "Odesolve" operator in Mathcad software (Fig. 3).

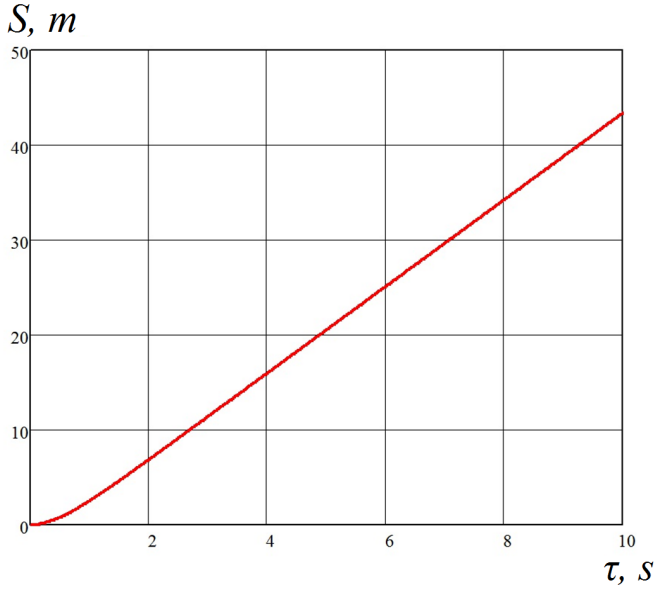

Fig 3. Dependence of the passed distance by the drop on the residence time in the central zone of the vortex granulator

Average density of the irrigation:

$$g = \frac{G}{\pi \cdot R_{ir}^2}. \qquad (22)$$

Conclusion

The proposed organization of the flow motion and the vortex granulator's design to implement this method let to achieve a positive result during the drop formation and stabilization of its shape. The drop moves in an ascending gas flow, and based on theoretical calculations, it is possible to obtain the design properties of the vortex granulator's central zone and the technological parameters of the gas flow (at which it is possible to reach the minimum height of the central zone). In this case, the general calculation algorithm of the vortex granulator with the proposed design will consist of two blocks: the calculation of the drop crystallization block (hydrodynamic calculation is given in this article) and the calculation of the granulation process in a vortex gas flow (theoretical model for calculation).

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Improvement of the Convective Drying Efficiency in Devices with Weighted Layer: Multistage Drying in the Shelf Devices

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Abstract – The work demonstrates main principles to improve the convective drying in devices with the weighted layer. Methods for drying process intensification are proposed in the task of the external and internal heat-mass transfer. The possibility to use gravitational shelf dryers to improve the drying efficiency is substantiated. The theoretical results regarding the time, the granule stays in the dryer's workspace, temperature and humidity properties of the dispersed material under various methods of drying agent's motion organization are represented.

Keywords – convective drying, intensification, gravitational shelf dryer, optimization

Introduction

Most dried materials form the dispersed phases of organic and inorganic origin. In order to realize this process, devices of various constructions depending on the method of drying of raw material, have been investigated and introduced into production [1–3]. The convective drying is one of the most effective methods of moisture removal from the dispersed materials [4, 5]. Thanks to the opportunities in the implementation and in the technological realization, this type of drying is used almost for all dispersed (granular) products in the chemical, food and pharmaceutical industry [6, 7].

One of the convective drying methods is a contact of the material with a heat transfer agent in the stationary, semi-weighted or weighted state, which can take place in drum dryers, devices with fluidized bed, in pneumatic pipe-dryers and devices of other constructions [1, 2].

Each of the above equipment types is characterized with some disadvantages: drum dryers and devices with the fluidized bed are large and have great energy intensity, pneumatic pipe-dryers do not provide the necessary contact time of wet material with a heat transfer agent and are characterized with high altitude [1, 2, 8, 9].

Taking into account the considerable influence, made by the design of the device, and technological parameters of its operation searches for new high-efficient methods of convective dehydration of granular materials are being conducted. Gravitational devices with vertical sectionalization of the inner space are one of the promising constructions, which takes an intermediate position between the devices of the fluidized bed and the pneumatic pipes.

Multistage devices with inner inserts in the form of shelves are widely used, for example, for cooling and pneumatic classification [10]. Until recently implementation of these devices as dryers has been limited to the experimental samples due to the lack of knowledge regarding the mechanisms to regulate the process at every stage. The first works, which deal with the implementation of shelf devices in the drying technology provide the relevant theoretical and experimental base to calculate the motion of the flow hydrodynamics, dehydration kinetics. The shelf dryer has been successfully tested in the technology of porous ammonium nitrate production at the final drying stage [11–13] after vortex granulator [14, 15]. However, the problem to form methods to change features of the directed fluidized bed of the dispersed material and influence, made by the method of the drying agent's flow organization, on the intensity of the moisture removal from the material, has not been solved yet.

Although energy consumption during the convective drying are not the lowest, the convective dryers are more often used for dispersed materials drying thanks to other numerous advantages [1, 2]. Provision of the active hydrodynamic regime in such dryers helps intensify the process without reduction of the economic efficiency of their operation and has the following advantages [3, 11, 12]:

- hydrodynamic stability of the process;
- increase of the relative motion velocity of the interacting phases;
- the developed surface of the contacting phases;
- approximation of the hydrodynamic model of flows in the device to the ideal displacement model;
- reduction of the energy intensity of the process and metal intensity of devices.

The fig. 1 demonstrates the main methods of convective drying intensification in the part of the external and internal heat and mass transfer. It is often difficult to use all methods simultaneously, that is why the most effective methods for this device are preferred.

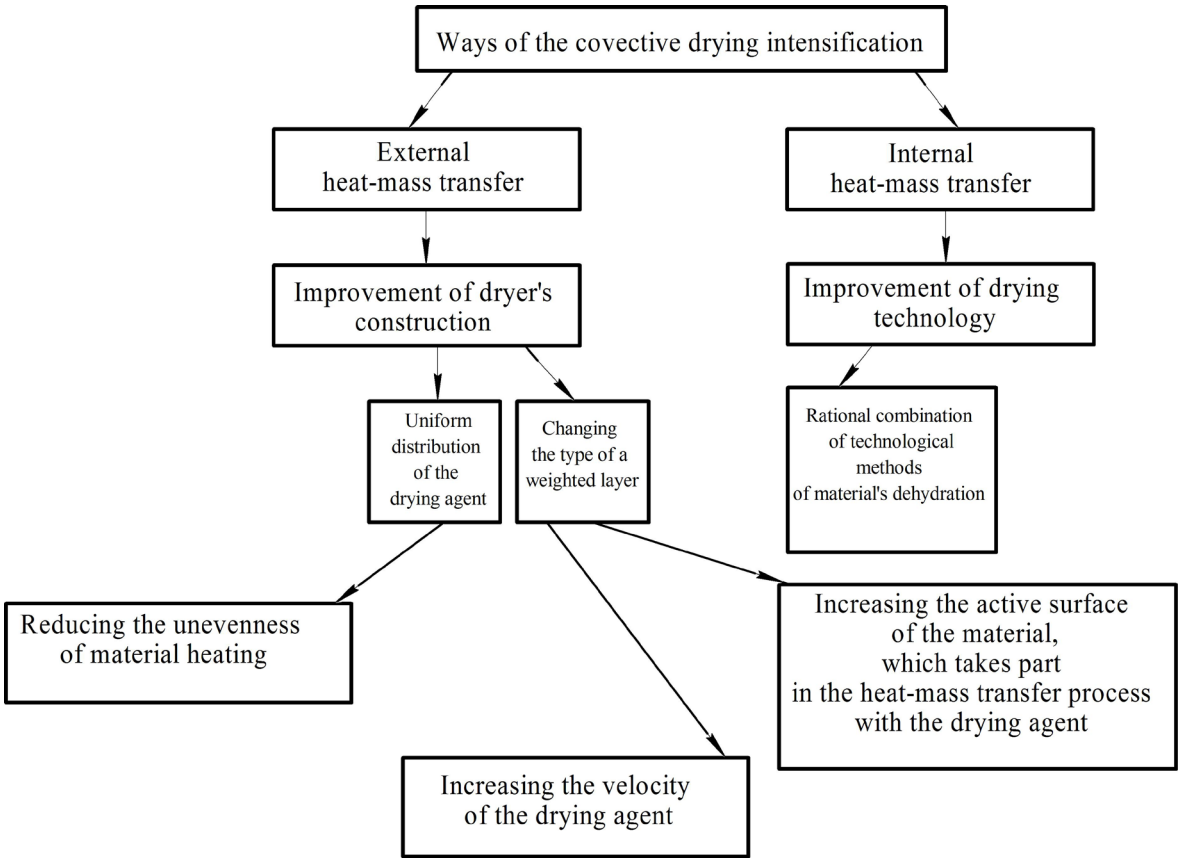

Fig.1. Ways of the convective drying intensification (for dispersed materials)

This work will consider tasks regarding the improvement of dryer's construction (changing the type of a weighted layer) and improvement of drying technology (a rational combination of technological methods of material's dehydration, in particular, choosing the way to organize the drying agent's motion).

Theoretical Basis

Owing to the repeated contact of the dispersed material with a drying agent in the gravitational shelf dryers, energy consumption per removed moisture unit is reduced. Therefore, the additional growth of the relative amount of the removed moisture can be achieved by increasing the time the material stays at every dryer's stage and the artificial increase of the drying agent's temperature potential (introduction of the drying agent's part after every dryer's

stage). Identification of the time the dispersed phase stays in the shelf dryer (the model is based on [16].

The study proposes an approach, based on the investigation of the mechanism to control the particle's motion time owing to changes of the shelves number n and their construction – length L_s, tilt angle γ and perforation degree δ. Thanks to the construction changes, the gas flow velocity V_{work} is also changed in the above-shelf space.

The mathematic model to calculate the time the particles stay in the perforated shelf includes the following formulas (the model is based on [17]).

Second critical velocity, m/s

$$V_{cr} = 1,63 \cdot \sqrt{\frac{\rho_{gr} \cdot g \cdot r_{gr}}{\xi \cdot \rho_g}}, \qquad (1)$$

where ρ_{gr} – density of granule's material; ρ_g – density of gas; g – gravitational acceleration; r_{gr} – the radius of granule; ξ – coefficient of aerodynamic resistance.

Time of material residence on the shelf (free movement), s

$$\tau_f = \frac{L_s}{\Delta V \sin\gamma}. \qquad (2)$$

Velocity difference, m/s

$$\Delta V = V_{cr} - V_{work}, \qquad (3)$$

where V_{work} is determined depending on fluidized agent flow rate and constructive fulfilment of the perforated shelf.

The empirical function of the effect of compression on the residence time of the particle in the working space of the device

$$f_{e\tau}(\psi) = (1-\psi)^{-m}, \qquad (4)$$

where ψ – volumetric content of granules in a two-phase system; m – coefficient that taking into account the type of hydrodynamic system.

Time of material residence on the shelf (straitened movement), s

$$\tau_s = \frac{L_s \cdot f_{e\tau}(\psi)}{\Delta V \sin\gamma}. \qquad (5)$$

Having calculated τ_f and τ_s by formulas (2) and (5), there is an opportunity to define the distance l the particle shifts during any period of time within $\left[0;\tau_f\right]$ and $\left[0;\tau_s\right]$. This distance can be calculated by formulas (6) and (7)

$$l_f = \tau_f \cdot \Delta V \sin\gamma, \qquad (6)$$

$$l_s = \frac{\tau_s \cdot \Delta V \sin\gamma}{f_{e\tau}(\psi)}. \qquad (7)$$

Selection of the optimal organization of the drying agent's motion (the model is based on [17].

Kinetics of the process regarding the temperatures for *i*-degree of drying

$$\frac{t_{i-1} - t'_i}{t_i - t'_{i-1}} = exp(-A\tau), \qquad (8)$$

where A – kinetic temperature parameter of the process; t'_i, t_i – temperatures of material and drying agent in the *i*-degree of dryer respectively, °C.

Kinetics of the water vapour transfer:

$$\frac{x_i - b_{i-1}}{x_{i-1} - b_i} = exp(-B\tau), \qquad (9)$$

where B – kinetic parameter of the moisture transfer; x_i, b_i – humidity of the material and drying agent in i-degree of the dryer respectively, kg/kg.

Equation of the thermal balance between flows of the dispersed material and drying agent

$$Gc_m(t_i' - t_{i-1}') + Gc_w(x_i t_i' - x_{i-1} t_{i-1}') = Vc_{dr.a}(t_i - t_{i-1}) + Vc_w(b_i t_i - b_{i-1} t_{i-1}), \quad (10)$$

where G, V – rate of the material and drying agent respectively, kg/s; c_m, c_w, $c_{dr.a}$ – heat capacity of the material, water and drying agent (air) respectively, J/(kg·°C).

The equation of the material balance between the humidity of the flows in the material and drying agent, which are interconnecting in the contraflow mode:

$$G(x_{i-1} - x_i) = V(b_{i-1} - b_i). \quad (11)$$

Results and Discussion

Identification of the time the dispersed phase stays in the shelf dryer

Based on the mathematic model, the first block of the software product Multistage fluidizer® [18], which lets to carry out the optimization calculation of the time the dispersed phase stays in the free and constraint motion regime at every stage of the shelf dryer. Some results of the calculation are shown in fig. 2. The program enables to vary the length of the shelf, its free intersection and tilt angle, and relative content of particles in the device to achieve the required time the material stays in the device. The required time, the material stays in the dryer, is defined by the kinetics of heating or dehydration.

Fig.2. Results of calculation

Several schemes to organize the drying agent's motion, shown in fig.3, were selected for calculation.

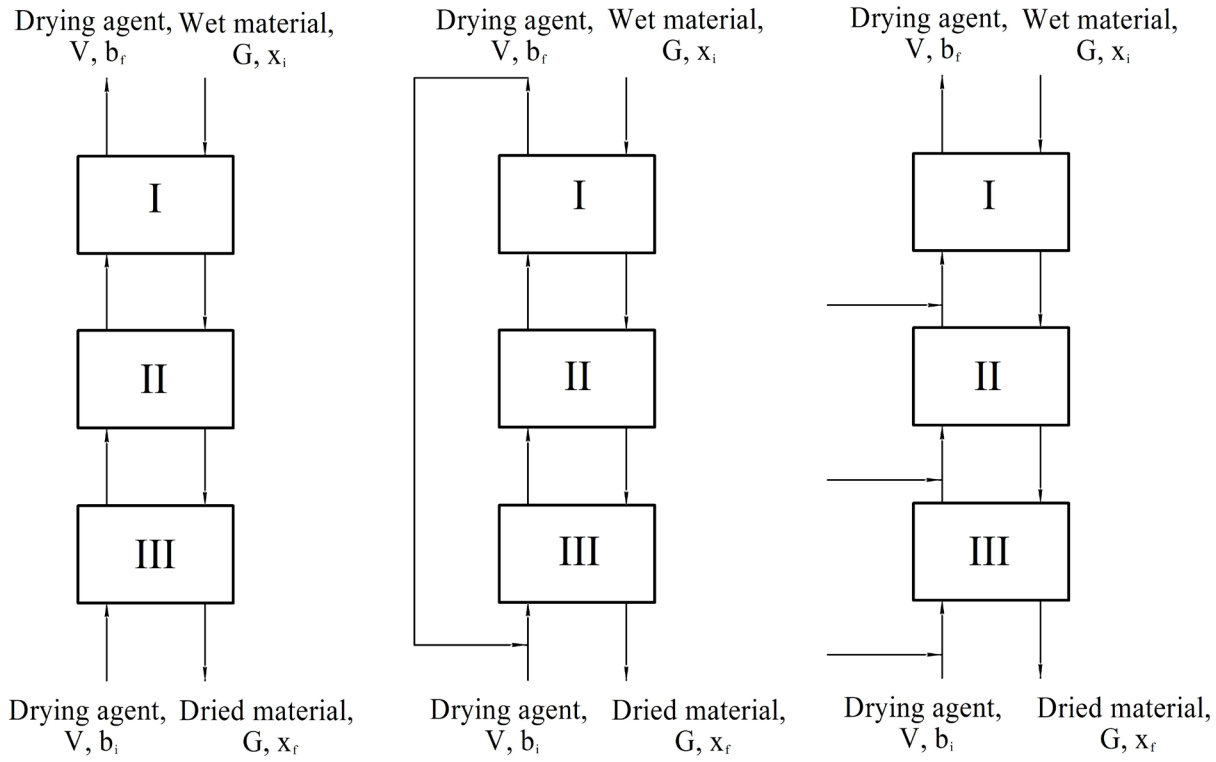

Fig.3. Variants for the organization of the drying agent's motion: a – contraflow without recirculation and bypassing of the drying agent; b – contraflow by the recirculation of the drying agent; c – contraflow with bypassing of the drying agent

Table 1 demonstrates the calculation results of the temperature-humidity peculiarities of the dispersed material using the software product Multistage fluidizer®. The gravitational shelf dryer worked in the weighted layer mode, which was chosen as an optimal mode according to the data [11]. The initial temperature of the drying agent for the performed experiment range within 90–140 ºC depending on the organization of the motion of the flow (maximum value for contraflow without recirculation and bypassing of the drying agent).

Conclusion

The results of the optimization calculation using the software product Multistage Fluidizer® will provide:

- minimum "hydrodynamic" time, the particle stays in the device, which will not exceed the "thermodynamic" time (minimum time of particles dehydration to the standard indicator; it is defined by the kinetics laws of the moisture removal, thermodynamic indicators of the dehydration process);
- using the various temperature and humidity potential of the heat transfer agent at every shelf;
- various shelf design at every stage of contact between heat transfer agent and particles;
- possibility to create the shelf contact, which changes its construction by length (different tilt angle of sections, various perforation of each section);
- ability to use recirculation of the heat transfer agent.

The task for further studies is to investigate the specified mathematic model to calculate the time, the dispersed material is in the shelf dryer. This model has to consider changes in the drying agent's velocity in the above-shelf space of every stage in the device.

Table 1

The theoretical calculations results of the final humidity of the dispersed material depending on the organization of the drying agent's motion (through the example of the sunflower seeds drying, only temperature-humidity properties of the dispersed material are given)

Organization of the drying agent flow	The flow rate of the material G, kg/h	The initial humidity of the material x_i, %	The initial temperature of the material t_i, ºC	The final humidity of the material x_f, %	The final temperature of the material t_f, ºC	The flow rate of the drying agent V, kg/h
Contraflow without recirculation and bypassing of the drying agent	36	13	20	7.3	45	108
Contraflow with one-time complete recirculation of the drying agent	36	13	20	10.2	34	108
Contraflow with bypassing of the drying agent before the second degree	36	13	20	7.1	43	72+36
Contraflow with bypassing of the drying agent before the third degree	36	13	20	7.8	41	72+36
Contraflow with recirculation of the drying agent (50% of total usage rate)	36	13	20	8,6	39	108
Contraflow wth recirculation of the drying agent (25% of the total rate)	36	13	20	8.2	40	108
Contraflow with bypassing of the drying agent before the second degree	36	13	20	7.1	45	72+36
Contraflow with bypassing of the drying agent before the second degree	36	13	20	7	47	72+36
Contraflow with bypassing of the drying agent before the third degree	36	13	20	6.8	49	72+36

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Investigation of Swelling and Permeability of Hydrogels Based on Copolymers of 2-hydroxyethyl Methacrylate with Polyvinylpyrrolidone

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Abstract – Hydrogels for biomedical purposes based on copolymers of 2-hydroxyethyl methacrylate with polyvinylpyrrolidone was synthesized. The influence of received compositions components, the effect of nature and the amount of solvent on the structure, the degree of swelling and permeability of the synthesized hydrogel membranes was introduced.

Keywords – 2-hydroxyethyl methacrylate, polyvinylpyrrolidone, hydrogel, swelling, permeability.

Introduction

The hydrogels consist of hydrophilic polymer matrices of three-dimensional structure, they do not dissolve when, adsorbing water (swelling) and form an insoluble product. The insolubility and the three-dimensional structure is induced by the presence of crosslinks between macromolecules. Due to the balance of the elasticity of the crosslinked polymer and the osmotic forces, that are acting on the liquid side, the net is stable. The chemical composition and molecular weight of the interstitial segments determine the density of the crosslinks, which determine the porosity of the hydrogel [1, 2]. During swelling, a physical transition to the highly elastic state of the polymer occurs. High water content and elasticity make the hydrogels similar to biological tissue. Hydrogels are widely used for biomedical purposes, in particular for the covering and treatment of wounds, hemodialysis, the creation of artificial skin, the production of drug delivery systems, etc. [1-3].

The properties of the hydrogel highly dependent on the number and distribution of the crosslinks. The crosslink density is measured by the average molecular weight of the polymer chains placed between the crosslinks. The density of crosslinking directly affects the basic properties of the hydrogels, such as the degree of swelling, mechanical strength and elasticity, permeability and even diffusion [1, 4]. These properties are experimentally and theoretically determined, what allows to modify the structure of the hydrogels.

A parameter such as the degree of swelling of the hydrogel, or the amount of water absorbed, is the determining physical property of the hydrogel. Swelling is highly dependent on the chemical structure of the polymer and inversely proportional to the density of the crosslinking. The nature of the side groups on the polymer matrix and the structure of the macromolecules influence the swelling. Hydrogels containing hydrophilic groups swell more intensively than those containing hydrophobic ones [1]. Accurate determination of swelling balance helps to calculate the crosslinking density, pore size of cell, and diffusion coefficient. Experimental methods for measuring hydrogel swelling include gravimetric measurements with immersion in water, using torsion scales and special tools for measuring size changes [5].

The porosity of the hydrogel ξ, or pore size, is a structural property that characterizes the distance between adjacent crosslinks in a polymer. The porosity depends on the density of the crosslinks, the composition of the monomer units and the concentration of the original monomers [4]. For an inert net and homogeneous porosity changes, the size of the cell is larger, the greater the swelling is [6].

The rate of diffusion of a water-soluble substance is important in determining the rate of drug release from hydrogel or nutrient transport. Diffusion depends on many factors, including net morphology, polymer composition, water content, solute and polymer concentration, gel degree of swelling [4]. When combined, these factors can cause chemical or frictional effects, which slow down the diffusion of the solute. The chemical effect consists on the forces of attraction between the solute and the hydrogel matrix, and the volume physical effect is the main friction factor affecting diffusion through the hydrogel [6].

Material and Methods

The hydrogels based on the reaction compositions of 2-hydroxyethylmethacrylate (HEMA) and polyvinylpyrrolidone (PVP) were synthesized. HEMA (Bisomer® trademark), which was purified by vacuum distillation at 78°C and a residual pressure of 130 N/m^2, PVP (SIAL Sigma-Aldrich® trademark) of qualification "pharm." with a molecular weight of $10 \cdot 10^3$ g/mole, as initiator was used potassium persulfate (KPS) which was purified twice by recrystallization from water solution.

Samples of hydrogels in the form of films by polymerization of the compositions HEMA – PVP – aqueous (aqueous-organic) medium in special closed-type forms were obtained according to the method and modes described in [2]. Determination of the structural parameters of the net, the degree of swelling in water and the permeability of water-soluble model low molecular weight substances in the process of osmosis were investigated by the methods described in [7, 8]. The thickness of the hydrated hydrogel film membranes was 200 μm.

Result and Discussion

Water-soluble sodium chloride, urea and sucrose were used to determine the permeability of the hydrogel membranes. The results of the investigation are shown in Table 1 and Table 2.

Table 1

The dependence of the permeability coefficient (k_{H_2O}) of hydrogel membranes, based on HEMA–PVP copolymers on their complex composition

No.	Content of the components, mass. p.			M_n, kg/mole	Water content, W, %	$k_{H2O} \cdot 10^4$, m^3/(m^2·h)
	HEMA	PVP	H_2O			
1	10	–	10	12	42	5,1
2	9	1	10	20	45	29,0
3	8	2	10	24	48	52,3
4	8	2	20	28	55	74,2
6	7	3	10	38	53	71,4

The analysis of the results showed that based on copolymers hydrogel film membranes, which contain PVP have a higher water permeability than membranes based on the HEMA homopolymer. This, in addition to hydrophilization, is a consequence of the so-called loosening effect. The PVP filling in has a similar effect on the permeability for low molecular weight substances (Table 2). Moreover, in a number of diffusing substances: sodium chloride – carbamide – the highest permeability is observed for the NaCl electrolyte, the lowest – for sucrose. When in solution as ions, sodium chloride can penetrate pores equal to the size of ions, through which diffusion of carbamide and sucrose with a higher molecular weight is prevented, also due to the hydrogen bonds with the polymer matrix formation.

Table 2

Hydrogel membranes, based on HEMA–PVP copolymers, permeability dependence

for low molecular weight compounds on their complex composition

No.	Content of the components, mass. p.			Permeability coefficient, mole/(m^2·h)		
	HEMA	PVP	H_2O	Sodium chloride	Urea	Sucrose
1	10	–	10	80	13	5
2	9	1	10	141	36	14
3	8	2	10	181	52	22
4	8	2	20	234	59	30
6	7	3	10	232	59	30

The permeability of the hydrogel membranes is influenced by the nature of the solvent (Table 3). The replacement of water with the mass fraction of dimethyl sulfoxide (DMSO) contributes to the increase of permeability, which confirms the assumption of a decrease amount of PVP that has copolymerised in DMSO medium [7]. As a result, a large amount of the PVP that is in an unbound state is capable of being withdrawed while hydratation, causing the loosening of the polymeric net (Table 4) and a increasing regular permeability. This reduces the density of the polymer net, which is characterized by the value of the molecular weight of the fragment between the two nodes of the crosslinking (Table 4).

Table 3

Hydrogel membranes based on HEMA–PVP copolymers permeability dependence on the nature and amount of solvent in the composition of the obtained complexes

No.	Content of the components, mass. p.				$k_{H2O}\cdot10^4$, m^3/(m^2·h)	k_{NaCl}, mole/(m^2·h)
	HEMA	PVP	H_2O	DMSO		
1	8	2	10	–	52,3	181
2	8	2	9	1	56,5	212
3	8	2	8	2	62,4	240
4	8	2	–	10	71,0	272
5	8	2	–	10 Ethanol	56,1	194

Table 4

Influence of solvent composition on interstitial molecular weight (M_n), water content (W) and permeability for water (k_{H2O}) of hydrogel membranes based on HEMA–PVP copolymers

No.	Content of the components, mass. p.				M_n, kg/mole	W, %	$k_{H2O}\cdot10^4$, m^3/(m^2·h)
	HEMA	PVP	H_2O	DMSO			
1	8	2	10	–	24	48	52,3
2	8	2	20	–	28	55	74,2
4	8	2	9	1	34	–	56,5
5	8	2	8	2	46	–	62,4
6	8	2	–	10	63	–	71,0
7	8	2	–	10 Ethanol	30	–	56,1

It was inestigated that the partial replacement of water with dimethyl sulphoxide in quantities that provide the existence of a charge-transfer complex (CTC) between HEMA and PVP, causes loosening at the molecular level and practically doesn't cause the increase in the dispersion of the microheterogenic phase and disperse medium. As a result this effect, the water content balance, as a measure of bound water, remains constant, although the molecular weight of the macrochain fragment (M_n) and the permeability to water significantly increases (Table 4).

In this case, M_n is derivative from the stability of CTC (Table 5), which makes it possible to use the stability constant of CTC in the obtained composition to predict the required permeability of the final copolymer.

Table 5

The constant of complex stability (K_{st}) on the structure and permeability of hydrogel membranes based on HEMA–PVP copolymers

No.	K_{st}, dm^3/mole	M_n, kg/mole	$k_{H2O} \cdot 10^4$, $m^3/(m^2 \cdot h)$	k_{NaCl}, mole/($m^2 \cdot h$)	$k_{Sucrose}$, mole/($m^2 \cdot h$)
1	0	54	71,0	272	31
2	0,16	35	58,4	240	28
3	0,20	30	53,1	212	–
4	0,28	24	50,3	181	21

Conclusion

Thus, research of hydrogels based on copolymers of 2-hydroxyethyl methacrylate and polyvinylpyrrolidone have shown that they are characterized by increased permeability to water and low molecular weight substances, in compare to homopolymers. The degree of swelling and permeability of the synthesized hydrogels in a wide range can be adjusted by the correlation of HEMA:PVP, as well as the nature and amount of solvent in the composition of the obtained complexes. The results can be used to obtain high-effective medical and cosmetic compositions, based on therapeutical substances.

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Synthesis of HgSe Films, Deposited from Potassium Rhodanide Aqueous Solution

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Abstract – The process of obtaining of mercury selenide (HgSe) films by a chemical bath deposition method with the use of potassium rhodanide as complex-forming reagent has been investigated. The phase composition, transmittion spectra, optical band gaps and surface morphology of HgSe films were studied.

Keywords – mercury selenide, films, semiconductors, chemical bath deposition, optical band gap.

Introduction

The one of least investigated material of $A^{II}B^{VI}$ group is mercury selenide (HgSe) films. One of the reasons of this is difficulty of its chemical bath deposition (CBD) due to the low product solubility and, as a consequence, the high rate of HgSe formation from an aqueous solution, which contains mercury and selenium. This problem can be solved by using a reagent that forms strong complexes with Hg^{2+}. The potassium rhodanide can be used as such reagent. However, the complex-forming reagents may have some effect on properties of deposited films.

Experimental

The CBD of HgSe thin films was conducted with the initial working solution, which consisted of mercury(II) nitrate ($Hg(NO_3)_2$), potassium rhodanide (KSCN), as complex-forming reagent of Hg^{2+} ions, and sodium selenosulfate (Na_2SeSO_3). The $Hg(NO_3)_2$ concentration in the working solution was equal to 0.01 mol/L; KSCN – 1.0 mol/L; Na_2SeSO_3 – 0.01 mol/L.

Only freshly prepared reagents were added to the working solutions for synthesis of HgSe films. The deposition duration and temperature was 80 min and 20 °C, respectively. The chemical deposition has carried out on pre-prepared glass substrates with an area of 3.24 cm^2. After the end of the reaction the substrates were eliminated; cleaned with a distilled water to take off the remains of working solution and dried in air.

The phase composition of HgSe films was investigated by X-ray powder diffraction (diffractometer DRON-3.0, Cu$K\alpha$- radiation).

The optical transmittion spectra of HgSe films were obtained with a spectrophotometer XION 500 (Dr.Lange). A comparative signal was passed through glass substrates identical to the substrates, used for the deposition of investigated films.

The investigation of surface morphology of the films samples were carried out using a raster scanning electron microscope (SEM) REM-106Y.

Results and Discussion

The X-ray analysis of HgSe films has been held. The cubic phase of zincblende (sphalerite) structure were identified on diffractograms.

The optical transmittion spectra $T(\lambda)$ HgSe films were investigated for wavelengths from 340 to 900 nm (Fig. 1). It has sharp increasing at ~400-500 nm region. The spectral dependences in $(\alpha \cdot h\nu)^2$ vs. $h\nu$ coordinates allow to determine the fundamental absorption edges. The optical band gaps of the HgSe films are localized in the ranges 2.08-2.95 eV, depending on the deposition duration.

The SEM investigation of HgSe films were made (Fig. 2). The particles of spherical-like form are observed on the surface of the samples. Their number and size increases with the increasing of deposition duration.

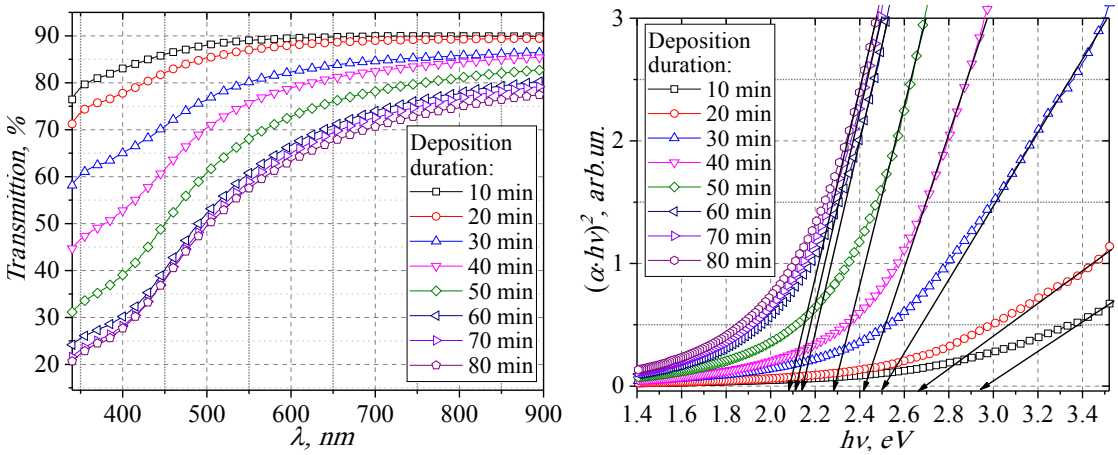

Fig.1. The spectral dependences of optical absorbtion of HgSe films (left) and $(\alpha \cdot h\nu)^2$ vs. $h\nu$ dependence (right) at different deposition duration

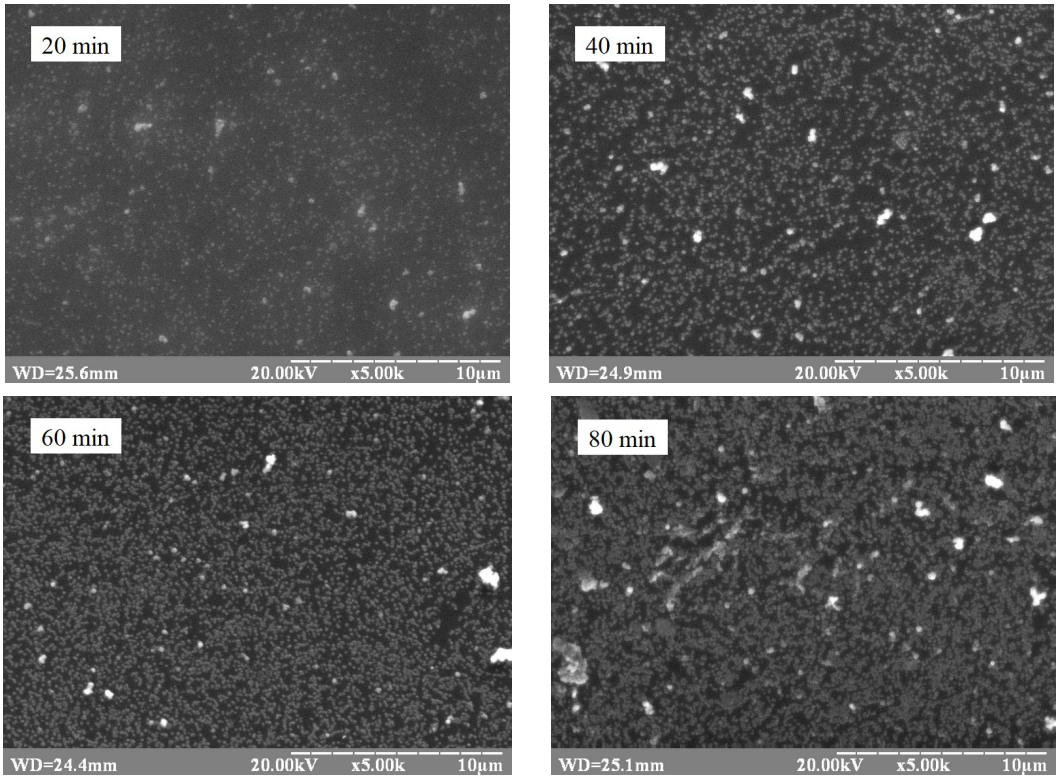

Fig.2. The SEM images of HgSe films, obtained at different deposition duration

Conciusion

The HgSe films were synthesized by the CBD method. For this, the KSCN have been used as complex-forming reagent for Hg^{2+} ions. The phase analysis, optical transmittion spectra and surface morphology of HgSe films were investigated. The positive research results of HgSe films synthesis allows to assuming that the KSCN and CBD method can be used to produce optical materials based on this coatings.

Acknowledgments

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Synthesis of New Monosubstituted Spiropentanes

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Abstract – Previously known spiropentane derivatives that were studied, were mostly represented by aminoacids. We present a pathway to other derivatives to diversify the extent of known spiropentanes, particularly the respective amidine, carboxylic acid, and hydrazine.

Keywords – cyclopropane, triangulane, spiropentane, intramolecular displacement, Grignard reagent, amidine, boronic acid, hydrazine.

Introduction

Cyclopropyl ring is a widely recognized fragment of many biologically active natural and artificial compounds. Considerably less attention was paid to a subset of spirocondensed cyclopropyl-containing structures known as triangulanes, most of which were studied for their physicochemical properties. The first member of the triangulane family, namely spiropentane, however, was studied for its biological activity, although the research quickly stagnated [1-4].

We would like to argue that such stagnation is a matter of onesidedness of the research that was carried out. The first attempt ever only assessed the biological activity of non-substituted spiropentane, and later studies examined the activity of spiropentyl-containing aminoacids. The latter is perfectly justified due to unique lengths and angles between functional groups that a spiropentyl ring can provide for its 1,4-disubsituted analogues, four pairs of diastereoisomers, as well as the fact that it is a rigid structure, so that the functional groups are unable to change their positions drastically. It is worth noting, however, that even monosubstituted spiropentane compounds exhibit biological activity, namely spiropentylacetic acid, therefore it is not necessary to obtain and study exclusively disubstituted spiropentyl compounds [2].

What we are trying to present here is a pathway to other monosubsituted spiropentane derivatives, in hope of sparking the interest towards them once again. We also believe that pathways offered here will find use in synthesis of more complicated structures in the future.

Results and Discussion

The first thing to consider in our endeavor was the choice of a starting reagent, which had to be available in considerable amounts. The compounds that readily contain spiropentyl ring are known to be rather expensive and are not available on scales of 10 to 100 grams. It was then decided that we would form the spiropentyl structure from a simpler compound.

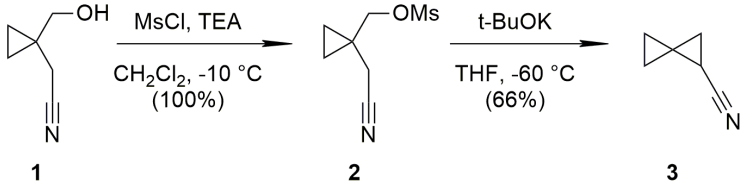


Fig.1. Spiropentylcarbonitrile **(3)** synthesis

We chose [1-(hydroxymethyl)cyclopropyl]acetonitrile **(1)** which is commercially available and abundant, and after subjecting it to nucleophilic substitution and subsequent intramolecular displacement, it furnishes us with spiropentylcarbonitrile **(3)** on scales of up to 40 g per procedure in good yields.

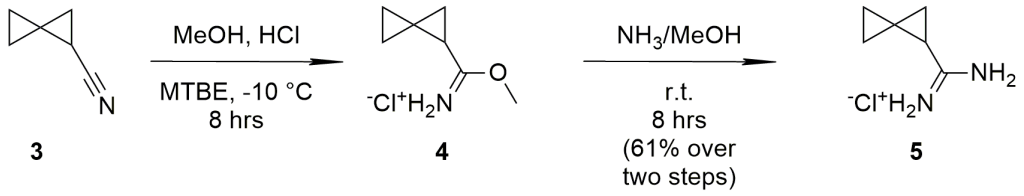


Fig.2. Spiropentylcarboxamidine **(5)** synthesis

The spiropentylcarbonitrile **(3)** can then serve us as a precursor to spiropentylcarboxylic acid **(4)**, which is a trivial fact, but it can also be converted to spiropentylcarboxamidine **(5)**, which is a prospective compound for various synthetic purposes. There are several approaches to performing this procedure [5], and we found that the treatment with methanol under flow of hydrogen chloride gas and subsequent reaction of formed aminoester with methanol solution of ammonia to be the most efficient and convenient, providing us with amidine hydrochloride **5** on preparative scales.

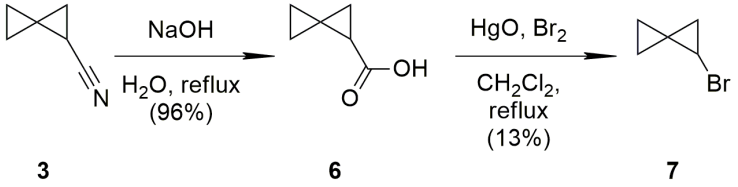


Fig.3. Bromospiropentane **(7)** synthesis

Conversion of nitrile 3 to acid 6, although trivial, was still exercised because the spiropentylcarboxylic acid **(6)** can then be subjected to a set of procedures we can call halodecarboxylation. In practice, out of several approaches, Cristol-Firth-Hunsdiecker reaction had shown the best results, with conversion of 50-70% of acid into bromide, but the isolate yields are quite low, mostlydue to low boiling point of bromide **7** and imperfect procedure of fractional distillation that had to be carried out several times, until sufficiently pure bromospiropentane **(7)** was obtained.

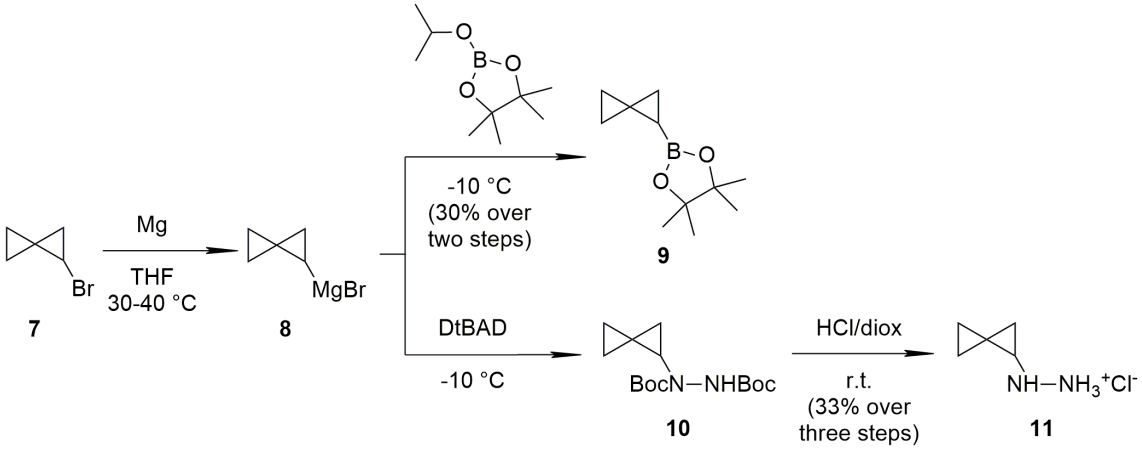
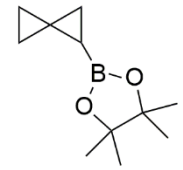
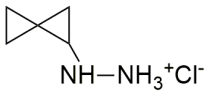
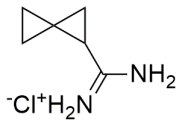


Fig.4. Synthesis of boronic acid ester **9** and hydrazine **11**

Even though the yields were low, we still managed to make the bromide **7** in amounts that allowed us to advance further, and although it is not new, it provides us the pathway to other compounds via conversion to Grignard reagent and subsequent treatment with respective substances to give spiropentylboronic acid **(9)** and spiropentylhydrazine **(11)**, which were obtained for the first time. The structures of compounds were confirmed by ^{1}H-, ^{13}C-NMR, MS, and elemental analysis.

Table 1

Spectral data of obtained spiropentyl compounds

Structure	^{1}H-NMR chemical shifts, ppm	^{13}C-NMR chemical shifts, ppm	Mass spectrometry data, m/z	Elemental analysis data, %
	0.75 (m, 1H), 0.73-0.91 (t m, 4H), 1.08 (m, 1H), 1.11 (m, 1H), 1.23 (s, 12H).	5.76 (CH_2), 5.60 (CH_2), 11.76 (CH_2), 15.06 (C), 24.50 (CH_3), 25.05 (CH_3), 82.90 (CCH_3).	194.1 (M^+), 179.1, 165.1, 151.1, 137.1, 124.1, 107.1, 101.1, 93.1, 84.1, 67.1 ($C_5H_7^+$), 55.1, 41.1.	C, 68.08; H, 9.87.
	0.75 (m, 3H), 0.93-1.11 (br t, 3H), 2.80 (m, 1H), 3.20-5.70 (br s, 3H), 8.30-9.90 (br s, 1H).	3.92 (CH_2), 6.19 (CH_2), 13.34 (CH_2), 15.13 (C), 36.47 (CH).	99.2 (M+1).	C, 44.58; H, 8.22; Cl, 26.33; N, 20.83.
	0.83 (m, 1H), 0.93-1.12 (br m, 3H), 1.60 (m, 1H), 1.69 (m, 1H), 2.21 (m, 1H), 8.61-8.81 (br d, 4H);	5.23(CH2), 7.23(CH2), 14.97(CH2), 18.77(CH), 19.78(C), 172.11 (C(NH)NH2).	111.2 (M+1), 83.2	C, 49.16; H, 7.54; Cl, 24.17; N, 19.13.

Conclusion

A convienient and preparative pathway to such spiropentyl compounds as nitrile, carboxylic acid, and amidine was developed. New approach to synthesis of bromospiropentane was developed as well, and later used to prepare spiropentylboronic acid pinacol ester and spiropentylhydrazine for the first time.

Such amidine, boronic acid ester and hydrazine present themselves as prospective reagents for organic synthesis, and also we believe that procedures described here can be also applied to other analogs, further diversifying the known extent of functionalized triangulane compounds.

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Anticancer Activity Studies of Isoquinoline Derivatives – Products of 3-(2-(thien-2-yl)thiazol-4-yl)isocoumarin Recyclization

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Abstract – A synthetic methodology for obtaining 1-functionalized isoquinolines starting with 3-hetarylisocoumarin has been developed. Studies of anticancer activity of 3-(2-(thien-2-yl)thiazol-4-yl)isocoumarin and the obtained derivatives have been performed on 60 lines of cancer cells in Cancer National Institute of the USA. The obtained compounds demonstrated a clear and strong correlation between anticancer activity and the character of substituents in the base structure, possessed a very low cytotoxicity, and performed well against several cancer types.

Keywords – isocoumarin, 3-hetarylisocoumarin, isoquinolin-1(2*H*)-one, 1-chloroisoquinoline, 1-amino-isoquinoline, recyclisation, anticancer activity.

Introduction

Compounds with the isoquinoline ring are a long- and well-known group of drugs. Their usage in medicine started with natural alkaloids of isoquinoline family.

Analyzing literature data on 1-amino-3-hetarylisoquinolines as potential anticancer agents, we realized that the number of known compounds of this type is quite limited, with the majority of them being derivatives presented in figure 1 [1]. Using molecular docking, the mentioned paper demonstrated that the anticancer activity of these compounds is based on the interaction with DNA (intercalation), and also on the inhibition of topomerase I and II *via* strong hydrogen bond formation. Yet, the question of importance of the aminogroup and whether similar molecules with a different polar group in position 1 would be biologicaly active remained open. Therefore, the goal of this paper is the synthesis of new 1-functionalized 3-hetarylchromones and studying the effect of substituents on their anticancer activity.

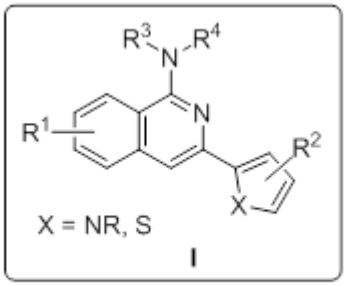


Fig. 1. 1-amino-3-hetarylisoquinolines

Materials and Methods

All chemicals used in the study were of the analytical grade and commercially available. All reagents and solvents were used without futher purification and drying.

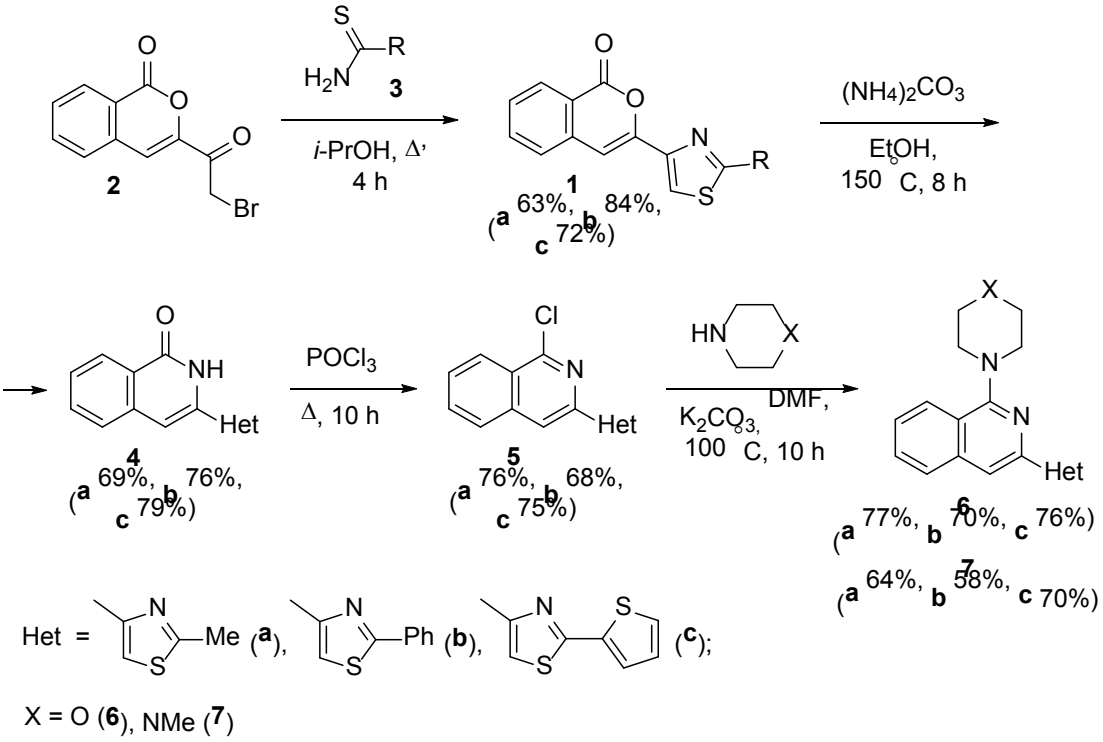
The structure of synthetized compounds was established with the help of ^{1}H and ^{13}C NMR spectroscopy and mass spectrometry.

Results and Discussion

3-(2-R-Thiazol-4-yl)isocoumarin **1** was obtained *via* heterocylization of 3-(α-bromacetyl)-isocoumarin **2** [2] with thioamide **3c** (Scheme 1).

The subsequent transformation of isocoumarins **1** into 3-(2-R-thiazol-4-yl)isoquinolin-1(2*H*)-ones **4** was performed by heating them with ammonium carbonate at 150°C in a hydrothermal autoclave (3 atm). Synthesis of 1-chloro-3-(2-R-thiazol-4-yl)isoquinoline **5** was performed by prolonged boiling of oxoderivatives **4** with phosphorus chloroxide. The replacement of chlorine atom of compounds **5** with morpholine and *N*-methylpiperazine moieties

occurred by heating the compounds in DMF in the presence of K_2CO_3. It should be noted that switching from chloroderivative **5** to 1-aminoisoquinolines **6, 7** significantly increases solubility which is beneficial for subsequent biological studies.



Scheme 1

All products were obtained in good yields (Scheme 1) which did not depend on the substituent in the position 2 of thiazole, making this methodology suitable for obtaining other 3-(thiazol-4-yl)isocoumarin and 3-(thiazol-4-yl)isoquinoline derivatives. The conversion progress was easy to control using NMR spectra. For example, the 4-H signal of the isocoumarin cycle is a singlet at 7.2–7.5 ppm, and the corresponding isoquinolone signal is in a slightly stronger field (7.0–7.4 ppm). The formation of chloroisoquinoline is evidenced by a sharp shift of this singlet to weak field (8.5 ppm), but replacing chlorine with an amino residue made the chemical shift of 4-H to be at 8.0 ppm again.

The study of anticancer activity of compounds **1c, 4c-7c** were carried out in the scope of international program DTP of National institute of health of the USA at the National Cancer Institute (NCI, Bethesda, Maryland, USA) with 60 lines of cancer cells. Table 1 lists sample data re the effect of studied compounds at concentration of 10^{-5} M on cancer cell growth, measured in % compared to the initial value: average value for all 60 lines, the value range, and top values for inhibiting certain cancel cell lines.

According to the data, the effect of isocoumarin **1c** on cancer cells confirms the importance of its heterocyclic derivatives as compounds with low toxicity. Most of values were not much different from 100% and the only data of interest are the ones re certain lung cancer lines. Isoquinoline-1(2*H*)-one **4c** was shown to be even less cytotoxic than the original isocoumarin, and a noticeable deviation from the average value was observed only with respect to one CNS cancer line (Table 1). Compound **5c** unexpectedly displayed low activity as well, despite the presence of a mobile chlorine atom.

Unlike its predecessors, amines **6c, 7c** demonstrated a much higher biological activity, especially the compound **7c** with *N*-methylpiperazine moiety which exhibited lethality (values of

growth inhibition less than 0%) towards six cancer lines (Table 1). In addition, the morpholine derivative **6c** was found to selectively inhibit the growth of one of seven studied colon cancer lines, one of six breast cancer lines, and also all melanoma lines.

Table 1

Compound / NCI code	Cancer cell grwoth, %		
	Average value	Value range	Smallest values (cell line / cancer type)
1c / NSC 814057	96.42	97.93	41.03 (T-47D / breast cancer) 47.68 (MDA-MB-468 / breast cancer) 54.41 (MCF7 / breast cancer)
4c / NSC 814058	101.66	78.57	51.94 (SF-268 / CNS cancer)
5c / NSC 814059	92.36	96.96	41.33 (T-47D / breast cancer)
6c / NSC 814061	86.18	123.47	0.58 (MALME-3M / melanoma) 5.77 (MDA-MB-468 / breast cancer) 17.32 (UACC-257 / melanoma) 20.45 (COLO 205 / colon cancer)
7c / NSC 814060	39.75	145.66	-51.14 (COLO 205 / colon cancer) -44.88 (M14 / melanoma) -38.24 (HCC-2998 / colon cancer) -35.92 (K-562 / leukemia) -27.28 (HT29 / colon cancer) -25.60 (NCI-H460 / non-small cell lung cancer)

Conclusion

The developed approaches to the synthesis of 1-functionalized isoquinolines starting with 3-hetarylisocoumarin are based on the use of simple methods and available reagents and provide a wide variety of target products, making them a good base for further biological studies. The study of anticancer activity of 3-(2-thien-2-yl)thiazol-4-yl)isocoumarin and its isoquinoline derivatives that was carried out on 60 cancer cell lines in the USA National Cancer Institute has demonstrated that 4-(1-(4-morpholin-1-yl)isoquinolin-3-yl)-2-(thien-2-yl)thiasole is sufficiently efficient against several cancer types: melanomas MALME-3M и UACC-257, breast cancer MDA-MB-468 and colon cancer COLO 205. 4-(1-(4-Methylpiperazin-1-yl)isoquinolin-3-yl)-2-(thien-2-yl)thiazole stops the growth of the majority of the studied cell lines; this compound is even lethal, in particular, for the COLO 205, HCC-2998, and HT29 colon cancer lines, as well as for the M14 melanoma line and the K-562 leukemia line. At the same time, the starting isocoumarin and 3-(2-(thien-2-yl)thiazol-4-yl)isoquinolin-1(2*H*)-on and 1-chloro-3-(2-(thien-2-yl)thiazol-4-yl)isoquinoline possess very low cytotoxicity and can only barely slow down the growth of certain cell lines.

Acknowledgments

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Kinetics of Aldol Condensation of Acetic Acid with Formaldehyde on Modified Fumed Silica Supported Catalyst

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Abstract – it had been demonstrated that hydrothermal treatment of support allows increasing activity and selectivity of the catalyst in the aldol condensation of acetic acid with formaldehyde. The kinetics of the reaction was studied and reaction scheme was proposed, that allowed to create a mathematical model of the reaction and to calculate kinetic parameters.

Keywords – acrylic acid, aldol condensation, heterogeneous catalysis, hydrothermal treatment, kinetics.

Introduction

Acrylic acid (AA) is one of the most important substances of organic synthesis. High reactivity of AA provides excellent performance properties of polymeric materials based on it (mechanical strength, high optical properties, resistance to external factors). Therefore, polymeric materials based on AA are widely used in various industries: synthesis of SAP (superabsorbent polymers), production of organic glass, paint and varnish, modifying additives to concrete and numerous other products of organic synthesis. [1-3] Today, the global AA market is ~ $ 550 million a year, about 40 countries are exporters of AA and over 100 countries are its importers. Therefore, the demand for AA is increasing every year. Today, the main industrial method of AA production is two-stage oxidation of propylene, which is raw material of petroleum origin. Given the high importance of AA the development of new alternative methods of its production is very relevant. [4]

Drawing on numerous studies, special attention is given to the method of gas-phase aldol condensation of acetic acid with formaldehyde, which is very promising due to the small number of stages of the process and the relatively low cost of raw materials, which determines its technological and economic advantage [5, 6]. The industrial production of AA by the method of aldol condensation of acetic acid (AcA) with formaldehyde (FA) has not been implemented to date, due to the low efficiency of existing catalysts for the process. Therefore, the creation of the new catalysts is an important scientific and technical task.

To date, catalysts of the basic type are commonly used for aldol condensation reactions, which provide acceptable selectivity, but the activity of these catalysts remains low. Acid type catalysts, on the contrary, provide a higher conversion, however, their use is accompanied by the formation of a large number of by-products [7 - 9]. It can be concluded that both basic and acidic properties of the catalyst are important for the process of aldol condensation. As a result, a number of scientific papers have focused on the development of modified acid-base bifunctional type catalysts. In previous studies, it was found that the catalyst with the composition B – P – V – W – Ox/SiO2 shows high results in the processes of aldol condensation of acetic acid with formaldehyde into acrylic acid [10]. A significant effect of the porous catalyst structure on the process was also established [11]. It is also known that different types of support treatment can change its crystalline structure, activate the surface and, as a result, change its catalytic properties. Therefore, it was decided to analyze the activity of the catalyst depending on the temperature of modification of the support.

Aldol condensation is an important organic reaction because of the formation of new C-C bonds; however, its exact mechanism on heterogeneous catalysts has not been established. So it

can be actual to study the kinetics of the reaction and to predict the reaction mechanism for creating the mathematical model, which will allow optimize the process.

Results and Discussion

In previous studies, the B–P–V–W–Ox/SiO_2 catalyst on the silica gel support showed the best result (conversion X = 74.3%, selectivity S = 90.5%, yield Y = 67.6%), with acetone (Ac) being the only by-product. However, given that the raw material for the production of silica gel is sodium silicate (Na_2SiO_3) - the resulting carrier contains impurities of sodium ions and other metals, which may negatively affect catalyst activity. Therefore, an fumed silica support (A-200) is selected as an alternative to silica gel. Fumed silica has a stable quality, due to the use of other raw materials and method of preparation. Also one of the advantages of an fumed silica is its domestic origin (Kalush, Ukraine). In previous studies it has been found that hydrothermal treatment (HTT) of support affects the activity of the catalyst [10]. Therefore, to establish the dependence of catalytic activity on the HTT of support, a series of experiments were conducted. The catalysts with different support modification temperature were compared Table 1.

Table 1

The catalyst activity depending on the temperature of modification of the support

	Conversion,%	Selectivity,%	Yield, %
Without treatment	66,5	91,2	60,6
HTT 100	60,7	92,4	56,1
HTT 125	69,9	93,7	65,5
HTT 150	71,7	92,3	66,2
HTT 175	73,1	94,1	68,6
HTT 200	72,7	91,1	66,3

The results show that hydrothermal treatment at 100 °C reduces the activity of the catalyst. This may be due to changes in the physico-chemical properties of the support, which require further investigation. With an increase in the treatment temperature of the support from 125 °C and above, there is an increase in all parameters of process efficiency, which confirms the general positive effect of HTT on the activity of the catalyst. It should also be noted that the catalysts on the fumed silica support exhibit higher values of AA selectivity (94.1%) compared to the previous best catalyst supported on silica gel (90.5%), again with Ac as the only by-product. Based on the obtained results, the catalytic system on the fumed silica support with a treatment temperature of 175 ºC is optimal for the process of aldol condensation of AcA with FA.

The next stage of the work was to perform a kinetic study of the condensation reaction of AcA with FA on the catalytic system of the composition B – P – V – W – O / SiO_2, with a HTT temperature of 175 ºC. The studies were conducted in a flow-type reactor with a stationary catalyst bed with low conversion of the initial reagents. The effect of concentrations of reagents (AcA and FA) on the rate of their conversion and the rate of formation of the reaction products were investigated. The concentration of AcA and FA was changed in the range of $1.12 \cdot 10^{-3}$ - $3.73 \cdot 10^{-3}$ mol / dm^3 and $1.27 \cdot 10^{-3}$ - $4.22 \cdot 10^{-3}$ mol / dm^3, respectively. As the concentration of one of the reagents changed, the concentrations of the others were kept constant by introducing helium into the reaction mixture. The kinetic experiment was performed at four temperatures: 563, 593, 623, 653 K.

From the experimental data, it was calculated that the rate of formation of AA in the presence of this catalytic system has an order about 0.7-0.9 in AcA, and 0.5-0.7 in FA, which

indicates the inhibition of the reaction by both acetic acid and formaldehyde. It was also found that the rate of formation of acetone has slightly less than zero order in FA, and is between 1 and 2 in AcA. It confirms that formaldehyde is not involved in the formation of acetone and inhibits this process. Based on this result, the following reaction scheme Fig. 1 is proposed:

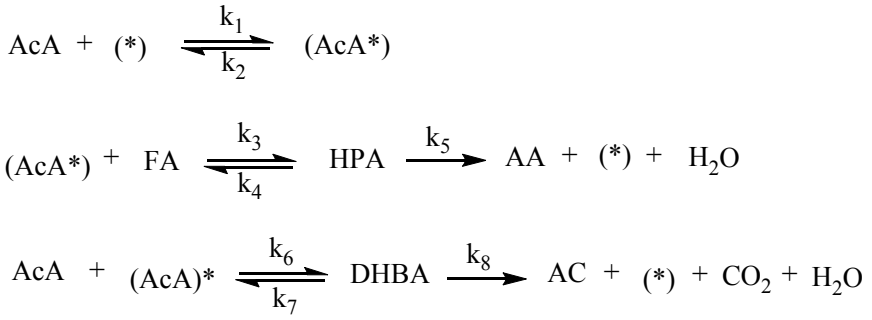

Fig.1. Reaction scheme

where: HPA – 3-hydroxypropionic acid; DHBA - dihydroxybutanoic acid; (AcA*) – adsorbed activated molecule of AcA; (*) - free active site of catalyst surface.
and the following kinetic equations were derived:

$$r_{AA} = \frac{k_1 \cdot K_1^{ef} \cdot C_{AcA} \cdot C_{FA}}{1 + K_1^{ef} \cdot C_{FA} + K_2^{ef} \cdot C_{AcA}} \quad (1)$$

$$r_{Ac} = \frac{k_1 \cdot K_2^{ef} \cdot C_{AcA}^2}{1 + K_1^{ef} \cdot C_{FA} + K_2^{ef} \cdot C_{AcA}} \quad (3)$$

$$r_{AcA} = k_1 \cdot \frac{K_1^{ef} \cdot C_{AcA} \cdot C_{FA} + 2 \cdot K_2^{ef} \cdot C_{AcA}^2}{1 + K_1^{ef} \cdot C_{фв} + K_2^{ef} \cdot C_{AcA}} \quad (2)$$

$$r_{FA} = \frac{k_1 \cdot K_1^{ef} \cdot C_{AcA} \cdot C_{FA}}{1 + K_1^{ef} \cdot C_{FA} + K_2^{ef} \cdot C_{AcA}} \quad (4)$$

where $K_1^{ef} = \frac{k_5 \cdot k_8 \cdot (k_7 + k_8)}{k_7 \cdot k_4 \cdot k_2 + k_7 \cdot k_2 \cdot k_5 + k_8 \cdot k_2 \cdot k_4 + k_8 \cdot k_2 \cdot k_5}$

$$K_2^{ef} = \frac{k_8 \cdot k_6 \cdot (k_4 + k_5)}{k_7 \cdot k_4 \cdot k_2 + k_7 \cdot k_2 \cdot k_5 + k_8 \cdot k_2 \cdot k_4 + k_8 \cdot k_2 \cdot k_5}$$

According to the proposed kinetic equations (1-4), kinetic parameters were calculated Table 2.

Table 2

Kinetic parameters of aldol condensation of acetic acid with formaldehyde on the optimum catalyst

T,K	$K_{ef1} \cdot 10^{-2}$, $dm^3/m^2 \cdot c$	$K_{ef2} \cdot 10^{-3}$, $dm^3/m^2 \cdot c$	$k_1 \cdot 10^{7}$, $dm^3/m^2 \cdot c$
598	74,08	18,21	1,71
623	88,71	32,23	2,38
648	124,07	44,37	3,21
673	143,69	71,97	4,91
E_a, kJ/mol	31,09	59,48	46,29

Conclusion

New B–P–V–W–O_x/SiO_2 catalysts have been synthesized for the gas-phase condensation of acetic acid with formaldehyde into acrylic acid with a support of domestic origin with stable chemical composition (fumed silica A-200). It was found that the developed catalyst is effective in the reaction of condensation of acetic acid with formaldehyde, which allows to obtain acrylic

acid with a yield of 68.7% and a selectivity of 94.1%. The kinetic regularities of the reaction on this catalyst have been established. According to the proposed kinetic equations, kinetic parameters were calculated that describe the condensation reaction of acetic acid with formaldehyde on the developed catalyst.

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Toxicological And Microbiological Assessment Of Oil-Polluted Soils In Biotechnological Decontamination

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Abstract – The paper is aimed to assess the toxicity level of oil-contaminated soils with different petroleum hydrocarbon concentration on test plants, and offer an effective way of bioremediation. The soil 8 % and higher oil content is highly polluted due to the sanitary and microbiological assessment and has a high level of toxicity in terms of all test- indicators for all test plants.

Keywords – bioremediation, biotesting, phytotesting, toxicity, oil degradation, oil-destructive bacteria, bacteria consortium.

Introduction

Soils contaminated with petroleum hydrocarbons have both a direct effect, connected with direct toxicity for living organisms, and an indirect effect on the soil biota, due to changes in habitat parameters. An increase in the amount of hydrocarbons in the soil leads to a decrease in species biodiversity and a reduction in the number of organisms that are more sensitive and less resistant to the toxic effect of incoming organic compounds. It has been established [1] that even the minimum concentration of oil in the soil contributes to the inhibition of the processes of energy and plastic exchange of nitrifying agents. Fluctuations of the amount of this group of microorganisms are identified as test reactions in the methods of bioindication of oil pollution [2]. At the same time, there is a growth of bacterial populations that specialize in the destruction of oil, carried out using synthesized endoenzymes. The results obtained by Gradova et al. [3] suggest the stimulation of the growth of nitrogen fixators in the course of oil and petroleum products entering the soil, which promotes the use of strains such as *Azotobacter chroococcum* and others to clean the contaminated environment.

According to Onwurah [4] crude oil affects germination and growth of some plants. Crude oil contamination of land affects certain soil parameters such as the mineral and organic matter content, the cation exchange capacity, redox properties and pH value. Onwurah et al. mentioned [5] high accumulation of aluminum and manganese ions, which are toxic to plant growth, in the result of anaerobic condition in the soil, coupled to water logging and acidic metabolites.

The results obtained by Sverdrup et al., Maliszewska-Kordybach et al. [6, 7] suggest the range 20–100 $mg \cdot kg^{-1}$ of individual polycyclic aromatic hydrocarbons (PAHs) concentrations are toxic to soildwelling species. Soil properties may also affect the concentration at which certain ecotoxicological effects may be noted. Date obtained as a result of research [8] and Tang et al. [9] indicated soils with high organic content reported toxic endpoints at concentrations at least double, and up to eight times, that of soils with low organic content.

The risk of drinking water contaminated by crude oil can be extrapolated from its effect on rats that developed hemorrhagic tendencies after exposure to watersoluble components of crude oil [10]. Other possible health effects of oil spill can be extrapolated from rats exposed to contaminated sites and these include increased liver, kidney and spleen weights as well as lipid per-oxidation and protein oxidation [11].

Phytotests are widely used to detect soil and water toxicity, in which plants are able to respond adequately to exogenous chemical effects by reducing the similarity of seeds, the intensity of germination of roots and shoots, and therefore act as indicators of toxicity [12].

Leme et al. in the research [13] used the following plant performance: root length, the mitotic index, the seeds viability, the length and weight of the overground / underground plants part, and the activity of catalase in the seedlings to evaluate a test-response during The *Allium cepa* onion test. A recent analysis [14] showed that both physical and chemical effects of oil pose negative effects of plant growth and root development of Italian ryegrass (*Lolium multiflorum*) and Birdsfoot trefoil (*Lotus corniculatus*) that were vegetable on oil- and diesel oil-amended soils.

Despite a certain toxicity level of oil on all living beings biochemical clean-up technologies based on biodynamic and biotechnological schemes are the most useful tools to solve the problem of oil decontamination. Results of numerical investigations confirmed efficiency of oil destruction by more than ten main bacteria genera including *Pseudomonas* sp. [15], *Rhodococcus* sp. [16] and others. According to the research of Hamme and Ward [17] *Pseudomonas, Sphingomonas,* Azadi et al. [18] *Mycobacterium, Bacillus* and *Rhodococcus* genera include bacteria that are capable of PAH destroying.

The bioremediation of oil-polluted soils for each specific situation requires a preliminary study of the sanitary and microbiological state of the soil and the level of toxicity to local biota.

Materials and Methods

Soil analysis

Soil samples were contaminationed with petroleum hydrocarbon in the result of oil spills during accident situations. Such samples with different oil content were collected near Kachanovka field of Dnieper–Donets oil and gas region (50°19′09″N, 34°36′29″E), Sumy region, Ukraine. Samples were collected during April. The top 20 cm of soil was collected using sterile spatula into sterile plastic bags for further transportation and microbiological analysis. Samples were stored at 4 °C until further processing. The experimental study was conducted at a temperature of 21 °C. The type of soil samples was chernozem typical leached deep low-humus large-cacked-light-argillaceous.

Physical and chemical parameters of the soil are shown in the table 1.

Table 1

Physical and chemical properties of soil samples

Parameters	Initial oil content (%)	Physio-chemical parameters		Soil nutrients (NPK)		
		pH	Total organic Carbon (%)	Phosphorus ($mg \cdot kg^{-1}$)	Nitrogen ($mg \cdot kg^{-1}$)	Potassium ($mg \cdot kg^{-1}$)
Uncontaminated soil (control)	0	6.6	1.00	192	123	185
Sample 1 (No.1)	2	6.5	0.44	106	71	109
Sample 2 (No.2)	4	6.7	0.36	98	64	99
Sample 3 (No.3)	8	6.8	0.31	86	46	83
Sample 4 (No.4)	12	6.9	0.27	78	39	67

Phytotoxic test

The study was carried out in accordance with the methodology described in DSTU ISO 11269-2: 2002 Quality of soil. Determination of contaminant action on the soil flora. Part 2: Influence of chemicals on germination and growth of higher plants. Plastic pots (0.5 kg) were filled according to the following experimental plan with five replicates for each treatment. Control and four test-pots with different amount of oil (No. 1 – 2%, No. 2 – 4%, No. 3 – 8%, No. 4 – 12%) were used for pot experiment. Each pot was sown with a 25 seeds/pot of oats (*Avena*), 30 seeds/pot of lettuce (*Lepidium sativum*) and wheat (*Triticum aestivum*). Pots from all the treatments were provided almost the same amount of water. The whole experiment was monitored for 21 days. The test response of plant performance was evaluated in terms of seed germination, root length and shoot length. Eqs. (1) and (2) were used to process the results and determine the phytotoxic effect (*PE*, %).

$$PE = \frac{B_0 - B_1}{B_0} \cdot 100\% \quad (1)$$

$$PE = \frac{L_0 - L_1}{L_0} \cdot 100\% \quad (2)$$

where B_0 is a germination in the control sample, units;
B_1 is a germination in an experimental sample, units;
L_0 is length of the root (shoots) in the control sample, cm;
L_1 is the length of the root (shoots) in the experimental sample, cm.

Microbiological state of the soil

Soil sanitary-indicative microorganisms: bacteria of the *E. coli*, enterococci, *Clostridium perfringens* and thermophilic microbes were studied to establish the microbiological state of oil-contaminated soil samples. The total microbial count, the number of bacteria in the group of intestinal sticks (titer of BGIS), the titres of enterococci, *C.perfringens* and thermophilic microorganisms, the total number and percentage of spores, the number of actinomycetes, fungi, aerobic cellulosic and ammonifying bacteria were determined for the complete analysis. The category of BGIS includes bacteria of the *Enterobacteriaceae* family, which combines the genus *Citrobacter*, *Enterobacter*, *Klebsiella*. These are gram-negative, non-protein, oxidazonegative sticks that ferment glucose and lactose to acid and gas at a temperature of 37 °C.

Table 2

Methods for determining the main microbiological indicators

Indicator	The name of used technique
Total microbial count	Sowing soil suspension on meat-peptone agar (MPA) by deep method
Titer BGIS	Direct sowing of the soil mash and Kessler's medium on the Endo medium
Perfringens titer	Sowing soil suspension on Wilson-Blair medium
The number of thermophilic bacteria in 1 g	Surface sowing on MPA
Mold fungi	Direct sowing soil suspension on Saburo medium

Data and statistical analyses

The statistical significance of the test response data from the phyto-testing study and microbiological indicators data was evaluated by Analysis of Variance (ANOVA). Data analyses for all the plant and soil parameters were done using Microsoft Excel and SPSS software packages. The data were considered to be significantly different if $P \leq 0.05$. Systematic error

shifts equally all indicators values were monitored during the experiment. This error was determined by measuring class accuracy of measurement. The statistical processing of the data involved the determination of errors in the arithmetic mean, variance, and standard deviation (t), which was calculated according to the Student-Fisher test. The difference between the arithmetic mean was taken as truer at the value of $t \geq 3$.

Results and Discussion

On the 21st day of the study, indices of test-response of test plants for oats, lettuce and wheat were obtained for germination energy, root and shoot lengths. The phytotoxic effect for *Avena*, *Lepidium sativum* and *Triticum aestivum* were obtained after results processing using Eqs. (1) and (2). Under the obtained results, graphs of the phytotoxic effect on the concentration of oil in the soil were plotted according to different indicators (Fig. 1).

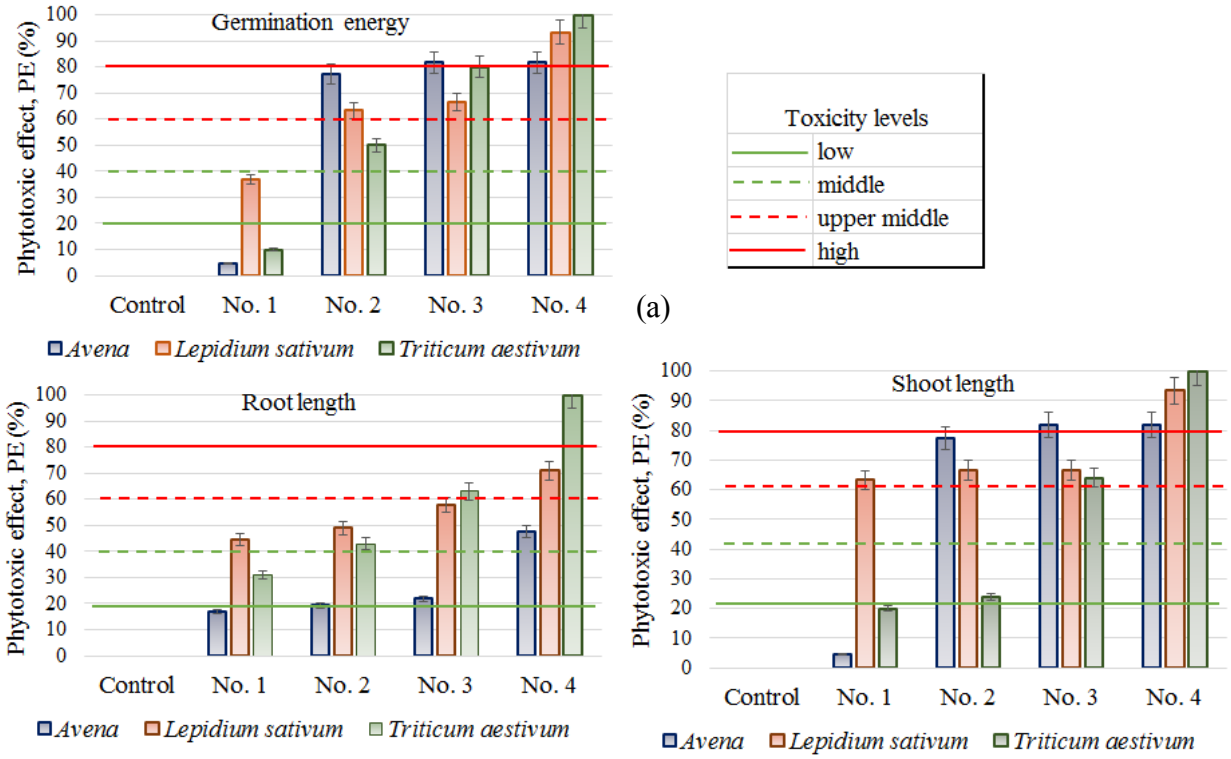

Fig.1. The dependence of the phytotoxic effect on the concentration of oil in the soil (germination energy (a), root length (b) and shoot length (c))

In the case of oil concentration in the soil at the level of 2 %, the level of toxicity for lettuce is observed in terms of shoot length upper middle and in terms of root length is middle. Soil contamination with oil at a level of 4 % had a minimal impact on the root length indicator for all tested plants, however, according to other indicators, the level of toxicity is defined as upper middle. Sample 3 with the concentration of 8 % showed less toxic impact for the indicator of root length (upper middle), but high toxicity level was observed for oats germination energy and shoot length. High toxicity level of 12 % oil contaminated soil was identified for indicators of germination energy and shoot length for all tested plants.

Thus, a high level of toxicity in terms of germination energy, root and shoot length indicators for all test plants is observed, starting from 8% of soil contamination with oil.

In addition to phytotesting, a sanitary-microbiological assessment of soil samples was carried out according to the method described above. The results of the study are shown in table 3.

Table 3

Results of sanitary-bacteriological examination of soil samples

Indicator	Control	No.1	No.2	No.3	No.4
Total microbial count, $CFU \cdot g^{-1}$	$4.5 \cdot 10^5$	$3.6 \cdot 10^7$	$5.1 \cdot 10^7$	$9.6 \cdot 10^8$	$9.2 \cdot 10^8$
Titer BGIS	2.0	0.8	0.009	0.004	0.001
Perfringens titer	0.01	0.009	0.00009	0.00009	0.00006
The number of thermophilic bacteria in 1 g	$5.0 \cdot 10^2$	$5.0 \cdot 10^4$	$5.0 \cdot 10^5$	$1.0 \cdot 10^6$	$5.0 \cdot 10^6$
Mold fungi, $CFU \cdot g^{-1}$	$5.0 \cdot 10^1$	$2.5 \cdot 10^2$	$1.3 \cdot 10^2$	$1.0 \cdot 10^7$	$1.0 \cdot 10^7$
Average soil pollution level	Clean	Moderately polluted	Heavily polluted	Heavily polluted	Heavily polluted

According to the results of the study of microbiological indicators of the soil was carried out sanitary and microbiological assessment of the tested samples. The control soil was clean in all respects. According to TBC indicators, all four soil samples are highly contaminated; in terms of the titer BGKP, perfringens-titer and the number of thermophilic bacteria in 1 g - sample No. 1 moderately polluted, samples No. 2, No. 3 and No. 4 are highly polluted; in terms of mold fungi, samples No. 1 and No. 2 are moderately polluted; samples No. 3 and No. 4 are highly polluted.

One microorganism is not capable of owning the entire spectrum of enzymes necessary for the biodegradation of oil, which is essentially a multicomponent mixture. Therefore, in the majority, it is proposed to use several strains that differ in the range of nutrient substrates and can lead to complete destruction of oil. Under conditions of natural microbiocenosis, simultaneous assimilation of different oil fractions by different groups of microorganisms is observed. In the soils are hydrocarbon-oxidizing bacteria, belonging to the genera *Pseudomonas, Rhodococcus, Mycobacterium, Kushneria, Ocenicoccus, Acinetobacter, Halotalea, Bacillus, Marinobacter, Spongiibacter*. When sharing several strains of destructors in the consortium, their oil utilizing effect is enhanced. A well-chosen culture or a mixture of strains of microorganisms under favorable environmental conditions: optimal temperature, salinity, pH, sufficient aeration, mineral nutrition elements, are able to utilize petroleum hydrocarbons.

To increase the efficiency of bioremediation, it is necessary to perform bioaugmentation, i.e. introduction of non-indigenous allochthonous microorganisms or cultivated indigenous species by inoculation or use of bioproducts to soil, which provides for the enhancement of the pollutants biodegradation.

In earlier study [19], it was indicated that the effectiveness of biodegradation in the use of biologics after emergency oil spills was 65–98 %, depending on the amount of spilled oil.

According to the metabolic information from KEGG database and Bacterial Diversity Metadatabase BacDive about predominant enzymatic systems and basic transformation (pathways) of important oil compounds, bacterial consortium was created in three different variants. The first one presents consortium for aliphatic hydrocarbons or paraffins (1), the second one – cycloalkanes (2), the third one – aromatic hydrocarbons (3). The corresponding histograms are shown in the fig. 2.

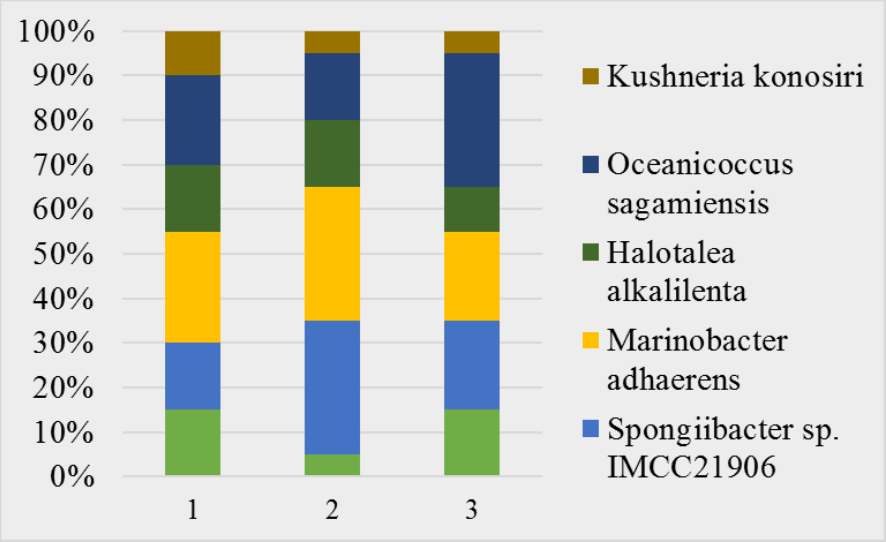

Fig.2. Histogram of ecological trophic groups involved in bioremediation

Thus, it is possible to simulate consortia of microorganisms for various components of oil and petroleum products that can alternately react with oxidation with intermediates.

Conclusion

There are various ways and reasons for the entry of oil and oil products into the environment. Bioremediation, as one of the ways to restore a polluted area, has a number of advantages and disadvantages, but the purification process is achieved through the natural flow or stimulation of environmental processes of pollutants destruction.

Since a single microorganism is not able to provide complete oil degradation, so using of the destructive organism consortium is the most effective clean up method. Oil concentrations in the soil with the high level of toxicity on various indicators of plant test facilities have been determined during laboratory studies and calculations. According to the results of the pot experiment, the most resistant to contamination by oil products is oats. Therefore, oats can be used for soil phytoremediation in conjunction with bioaugmentation to intensify oil biodegradation in the soil.

As a result of the experiment, groups of microorganisms were identified, in the presence of which it is possible to carry out a sanitary-microbiological assessment of the soil. Using bioinformatics databases, several variants of bacteria consortium that are capable of providing biodegradation of xenobiotic were designed.

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Development of intermetallic catalysts for the neutralization of carbon-containing components of gas emissions into the atmosphere

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Abstract - The aim of the work is the development of scientific technical solutions to protect atmospheric air from emissions that contain carbon monoxide and hydrocarbons. In the work were carried out comparative tests using the developed and existing catalysts for neutralization of the exhaust gases from the kiln. Tests for effectiveness of the catalysts were conducted in a stream of exhaust gases of kilns on the laboratory-scale installation at a temperature from 100 °C to 500 °C and volumetric flow rate (W) ranging from 30·103 to 120·103 m^3/m^3·hr. Application of the developed composition of the catalyst allowed to increase the degree of gases purification to 99.9%.

Keywords – gaseous waste, carbon oxide, hydrocarbons, neutralization, intermetallic catalyst, atmosphere air.

Introduction

The annual increase tendency of harmful emissions from industrial enterprises (by an average of 3-7%) is observed. Analyses show that about 10 million tons of harmful chemicals are released into the atmosphere annually; moreover, about 70% belong to the waste of stationary sources. This problem is particularly relevant to regions with a significant concentration of industrial enterprises. This fact underlines the urgency of solving the problem of health protection of population, which live in the industrially loaded territories [1, 2].

The most common pollutants are dust, sulfur compounds, nitrogen oxides, carbon monoxide and hydrocarbons, which are the main reasons of ecologically dependent diseases and states.

Power plants, internal-combustion engines, and industrial plants are the sources of the environment pollution with carbon monoxide (CO) and hydrocarbons (C_mH_n). Chemical and biological properties of CO and C_mH_n and their significant volumes in gaseous emissions increase environmental hazard around the facilities emitting them.

The concentration of CO and C_mH_n in the emissions produced by most of these sources does not meet the established standards and is a factor of intensive deterioration of the air quality [1]. In order to achieve the established standards, enterprises have to optimize their technological processes, introduce re-equipment and new technologies. The high environmental hazard of toxic organic substances determines the importance of the introduction of treatment technologies [1, 2].

Theoretical basics

One of the most effective ways of abatement of carbon oxide (CO) and hydrocarbons (C_mH_n) is the catalytic method. The catalytic process of neutralization of combustion products runs, as a rule, at temperatures above 300°C and under short contact times, due to the high flow rate of industrial emissions. The main advantages of the catalytic process in comparison with thermal afterburning consist in its technological and operational characteristics, namely: high efficiency and economy, the absence of harmful side effects.

The tightening of sanitary standards on environmental conditions requires searching for efficient catalysts for neutralization of exhaust gases of industrial plants [3].

For the catalytic elimination of CO and C_mH_n both metal and oxide catalysts can be used. However, upon utilization of the oxide catalysts, the sufficiently high speed of the contact process can be achieved only at relatively high temperatures (300-400° C). The oxides of some

metals may be arranged in the following sequence by the specific catalytic activity value [4]:

$$TiO_2 < V_2O_5 < Cr_2O_3 < ZnO < Fe_2O_3 < NiO < CuO < Co_3O_4 \quad (1)$$

The specific catalytic activity of the mentioned oxides at the temperature of 300°C differ by more than five orders of magnitude. Oxides of cobalt, copper, nickel and iron have the highest catalytic activity.

Metal catalysts have higher activity in the reaction with CO and C_mH_n than oxide catalysts. The metals may be arranged in the following sequence by the specific catalytic activity at the temperature of 180° C [4]:

$$V < Cr < Mn < Cu < Ag < Au < Fe < Co < Ni < Pd < Pt \quad (2)$$

Among the basic metals, the highest catalytic efficiency values belong to nickel, cobalt, and iron. What is more, by the specific catalytic efficiency nickel is superior to cobalt by 2.1 times and iron by 16 times. Platinum and palladium have the best properties for catalytic oxidation of CO and C_mH_n. However, platinum and palladium are slightly better than nickel by the specific catalytic efficiency: platinum is 6 times more efficient than nickel, and palladium is 5 times more efficient. On the other hand, nickel is much more active than oxide catalysts. The specific catalytic efficiency of nickel at the temperature of 180° C is 3 orders of magnitude higher than that of cobalt oxide, and 6 orders of magnitude higher than that of zinc oxide at 300° C. Thus, as low-temperature catalysts for CO and C_mH_n oxidation, nickel and cobalt catalysts make the most sense. Taking into account the higher activity and lower cost and scarcity of nickel as compared with cobalt, the choice of nickel catalysts for commercial use is the most rational. Thus, among the most effective catalysts are materials containing intermetallic compounds of nickel because of the ability to transfer active oxygen involved in the oxidation process. In this regard, it seems promising to study the properties of the intermetallic compounds of these metals as catalysts.

Experimental research

To reduce the emissions of CO and C_mH_n, an intermetallic catalyst was developed. It consists of nickel and aluminum with additions of copper, cobalt and manganese. The compound was produced by self-propagating high-temperature synthesis (SHS). Experimental-industrial tests of the developed intermetallic catalyst were carried out to neutralize the waste gases from the kilns at an electrode manufacturing plant.

We tested the catalyst of known composition (52% Al + 48% Ni), the catalyst containing 0.2 %wt of platinum which was spread on alumina and the new catalist which we have developed previesly with optimum composition of 30 % Ni + 10 % Co + 11 % Mn + 2 % Cu + 47 % Al [3-5].

The installation presented in fig. 1 [6] has been developed for studying the catalytic properties of intermetallid.

The catalysts activity tests were conducted in the waste gas flow of the furnace on the laboratory-scale installation at a temperature from 100 °C to 500 °C and volumetric flow rate (*W*) ranging from $30 \cdot 10^3$ to $120 \cdot 10^3$ $m^3/m^3 \cdot hr$. The concentration of hydrocarbons in the industrial emissions was measured by gas chromatography using the device “Crystal 2000 M”. The concentration of carbon monoxide was measured by means of the gas analysis instrument “Palladium-3”.

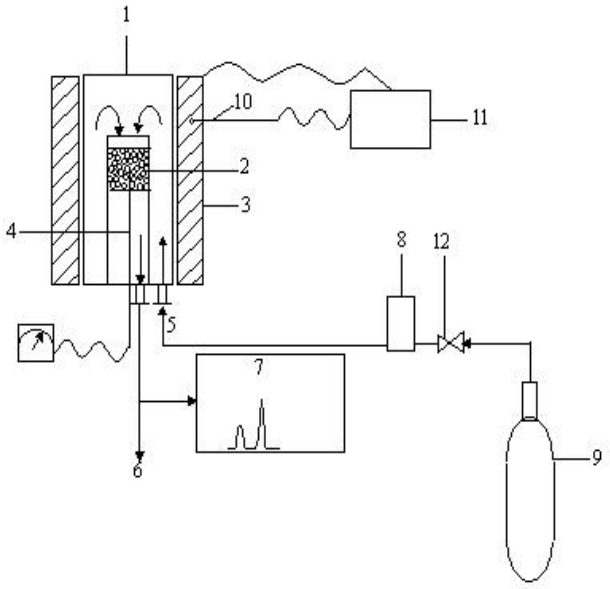

Fig.1. Installation for catalyst testing: 1 - reactor; 2 - catalyst bed; 3 - heating jacket; 4 - thermocouple; 5 - branch pipe for gas supply; 6 - branch pipe for gas removal; 7 - chromatograph; 8 - a rotameter; 9 - a balloon with a model mixture of gases; 10 - control thermocouple; 11 - reactor temperature maintenance unit; 12 - the regulator of the expense of a gas mix

The tests results conducted in the exhaust gases flow showed that the efficiency of the new proposed catalyst and the catalyst containing 0.2 %wt. of platinum differ slightly (Fig. 2, *a*, *b*). The highest degree of cleaning at a lower temperature was observed in both cases. In the flow with $W = 30 \cdot 10^3$ $m^3/m^3 \cdot hr$, under the influence of the catalysts the degree of CO neutralization reached 99.9 % at the temperature of 200°C. The same degree for C_mH_n was reached under 300°C.

The catalyst with the 52 % Al + 48 % Ni composition showed significantly lower activity. The oxidation of CO and C_mH_n was carried out in the flows with different volumetric flow rates. The results showed that with the increase of the volumetric flow rate from $30 \cdot 10^3$ to $120 \cdot 10^3$ $m^3/m^3 \cdot hr$ at the temperature of 300°C the degree of oxidation of CO and C_mH_n decreases from 99.9 to 95 % in case of using the new catalyst and the catalyst containing 0.2 %wt of platinum. For the 52 % Al + 48 % Ni catalyst the decrease was from 98 to 75 %.

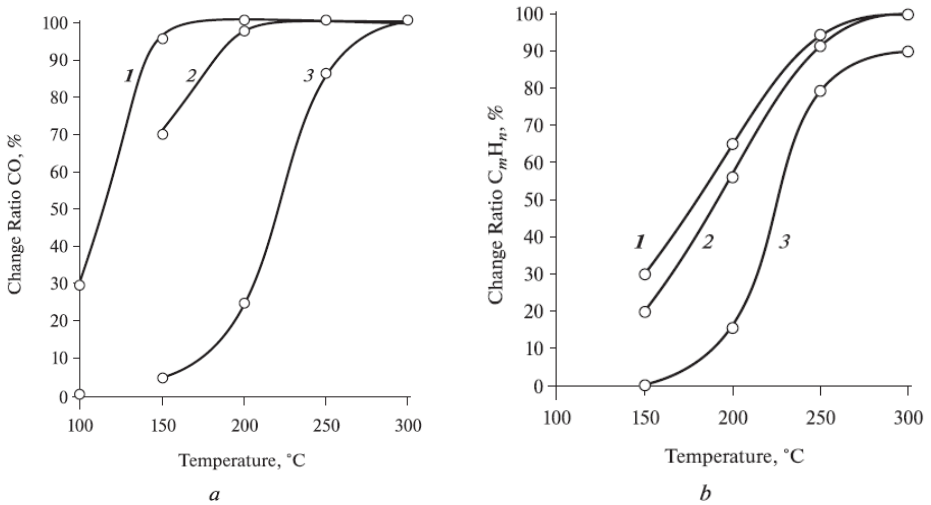

Fig. 2. Catalytic effect of the catalysts under review: a – in the oxidation of CO, %; b – in the oxidation of C_mH_n, %; 1 – Pt-catalyst; *2 – 30 % Ni + 10 % Co + 11 % Mn + 2 % Cu + 47 % Al; 3 – 52 % Al + 48 % Ni*

The catalyst with the composition of 52 % Al + 48 % Ni worked stably over 450 hours,

after which the degree of gas purification reduced sharply to 85 %. The new catalyst worked for 720 hours. The degree of purification reduced to 99%. As the exhaust gases from kiln contain SO_2, the activity of the catalyst with the composition of 52 % Al + 48 % Ni in the oxidation of CO and C_mH_n decreased after 10–20 hours of work because of poisoning; it appeared unstable towards SO_2. Over the new catalyst and the catalyst promoted with Pt, the presence of SO_2 causes a significant shift (by 200°C) of the curves of oxidation to the higher temperature region.

Complete oxidation of CO and 95 % C_mH_n in the presence of SO_2 was observed at temperatures of 450 °C, using new catalyst, and 400–420 °C, using Pt-catalyst at $W = 50 \cdot 10^3$ $m^3/m^3 \cdot hr$. New catalyst had been working for 600 hours.

The comparison of the results showed that in the conditions of thermal autoignition the new catalyst has substantial advantages with respect to the contacting temperature since it allows for temperatures of the process to lower by ≈80 °C. Its working duration in 1.6–1.7 times longer than the catalyst with the composition of 52 % Al + 48 % Ni, and its catalytic properties are equal to those of the catalysts containing noble metals. Based on the results we can propose the catalyst for industrial using [3-6].

For neutralization of kiln exhaust gases, we recommend the two-step cleaning scheme, according to which the first step is the cleaning of the gas by C-type electrostatic precipitator from resinous substances and the second step is the elimination of carbon monoxide in the catalytic reactor.

Using of the new catalyst ensures complete neutralization (99.9 %) of CO and C_mH_n in the kiln exhaust gas at the temperature of 300° C with the volumetric flow rate of 32000 h^{-1}, which ensures low energy consumption of the process.

Conclusions

To reduce emissions of CO and C_mH_n, an intermetallic catalyst of the composition 30% Ni + 10% Co + 11% Mn + 2% Cu + 47% Al was developed. Application of the developed composition of the catalyst allowed to increase the degree of gases purification to 99.9%. The results of comparative tests showed that the developed catalyst has a working life of 1.6-1.7 times greater than the known nickel catalysts. The catalyst of the developed composition can be used at the most diverse enterprises for CO and C_mH_n cleaning.

Acknowledgments

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In vitro storage of the unique genotype of ancient trees

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Abstract - In Ukraine, the priority is the preservation of virgin forests and centuries-old trees. However, the area of undisturbed forests is not large, and centuries old trees are concentrated in the central and northern parts. The practical significance of the work is to search new ways and methods of preservation old and ancient trees of Ukraine using modified approaches of plant biotechnology, which is one of way to maintaining the unique gene pool of mature, ancient and unique woody plants.

Keywords – centuries old trees, explant, microclonal propagation, regeneration, in vitro

Introduction

The mature trees are of great importance for providing a complex of ecosystem services, among which the most important are recreational and biodiversity conservation. Data on the ecosystem of the role of centuries-old trees are very limited and do not allow to form a full-fledged view of the ecological value of such representatives of the plant world.

Due to the natural aging condition, mature and ancient trees were characterized by high risk of extinction because of biotic, abiotic and anthropogenic factors and age.

Today in Ukraine and many countries all over the world one of the questions is how to protect and preserve ancient trees, as centuries-old, historical monuments of nature. The development of biotechnological methods can solve the problem of maintaining the unique gene pool of woody plants, study their ecosystem role and development of ornamental horticulture.

The main attention is focused on micropropagation the oldest trees of Lindens and Oaks in Ukraine, to study anatomical and microbiology peculiarities of explants on the separate stages.

Methods and research objects

As the source of explants ancient trees from natural conditions were used, such as: Oak of T. Shevchenko, (Kyiv) age over 600 years (fig. 1, a), Oak of Vetrov (NULES of Ukraine) (fig. 1, b) age over 300 - 400 year, Oak of M. Zalizniak, (Cherkasy r.) age over 1000 years (fig. 1, c), Oak of Rulskyi, age over 300-400 years (NULES of Ukraine) (fig. 1, d); Linden of T. Shevchenko, (Chernihiv r.) age over 600-800 years (fig. 1, e), Linden of P. Mogulu, (Kyiv) age over 800 years (fig. 1, f).

Branch tips from the lower branches of oak (*Quercus robur* L.) trees about 200 years old, and embryos with endosperm fragments, shoots and leaf blades, which were selected from 70 and 120 summer *Q. robur* donor plants in January-February and March-April 2016–2018were collected and used for awakening in the thermostat.

To sterilize the plant material were used next solutions: 70% ethyl alcohol, 0.1% $HgCl_2$, 1.0% $AgNO_3$ and 2.5% NaClO. The explants were cultivated according to the generally accepted method [5] on a nutrient medium according to the Murashige and Skoog (MS) and Wood Plant Media (WPM) formulations [6]. In our modified media, growth regulators of auxin and cytokinin type of action were introduced, 100 mg/l mesoinositol, 30 g/l sucrose, and 7.0–7.3 g/l

microbiological agar. Additionaly were used as antioxidants: activated carbon, glutathione, glycine and polyvinylpyrolidone (PVP). As a control, the hormone-free nutrient medium MS was used.

Fig. 1 Some Representatives of Ancient Trees of Ukraine (a,b,c, d, e, f): a) Oak of M. Zalizniak, age over 1000 years; b) Oak of T. Shevchenko, age 300 years; c) Oak of Vetrov age 300 years; d) Oak of Rulskyi; e) Linden of T. Shevchenko; f) Linden of T. Shevchenko.

Plant material was cultivated in a light room at a temperature of 25 ± 1 °C and illumination of 2.0–3.0 klx with a 16-hour photoperiod and a relative humidity of 70–75%.

After obtaining aseptic viable plant materials with using a range of antioxidants), they have been cutting on 1.0-1.2 cm fragments and transferred to the modified nutrient medium.

To increase the morphogenetic capacity of explants and to regulate the processes of morphogenesis nutrient media supplemented with cytokinin: 6-benzylaminopurine (BAP) 0.5 mg/l, thidiazuron (TDZ) (0.2-5.0 mg/l), pH value of the medium was 5.7.

Every 5 days (for 2 weeks of culture in vitro) the nodal explants were transferred to fresh WPM medium with 0.2-0.5 TDZ and complex of antioxidants. Shoot tips and nodal explants (0.5-1.0 cm long) that developed on the initial nodal segments were subjected to successive subculturing on WPM medium every 4 to 5 weeks.

Results and discussion

At first stages all explants were characterized by oxidation of plant tissues, because of phenolic activity.

The optimal explants for introduction to the culture in vitro were as winter shoots and awakening shoots had been getting from deferred shoot (fig. 2).

In spring-summer period the quantity of hormones, which put into the media equalize 0.2 mg/l, in autumn and winter period the necessity of supplemented of cytokinins become more important. In such a way into nutrient medium have been added 0.5 mg/l TDZ and 0.1 mg/l NAA with addition of Fe-EDDHA 4,8 % in certain stage of morphogenesis induction. Such treatment has been ensured the obtaining of a stable growing oak culture derived from old trees. The index of formation of primary microshoots from one explant reached 3-4 pcs. The frequency of formation of new microshoots reached 75.0 %.

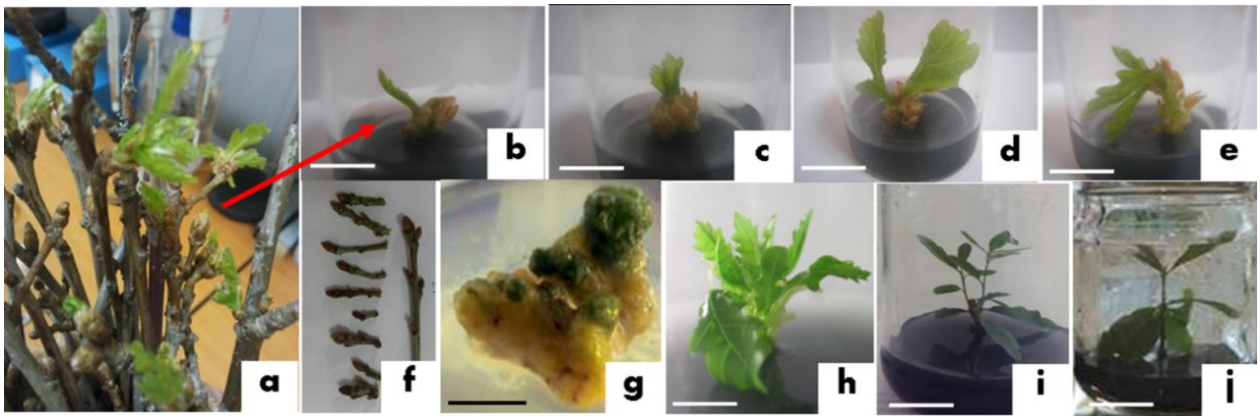

Fig. 2 In vitro culture of centuries Oak trees: a) awakened nodal segments and buds ; b), c), d) shoot induction from apical basis of bud; e) formation of microshoot from buds; f) shoot fragments of explants (the winter-spring period of time); g) axillary shoot induction and proliferation after subculturing (from nodal segment of basal part) on media with MS + Kn (0.5 mg/l) + TDZ (0.2-0.5 mg/l) + additives; i - multiplication and shoot elongation by proliferation of axillary buds on MS media supplemented with TDZ 0.5-1.0 mg/l and 0.2 mg/l NAA and additives; g) in vitro propagation on WPM containing 0.5 mg/l BA and 1.0 GA, 20 mg/l adenine, 2 g/l carbon.

Active in vitro shoot formation was recorded on MS media with addition of 1.0-2.0 mg/l 2iP (6- (ɣ, ɣ -dimethylamine) purine) and 20 mg/l -adenine. Single root rooting was odserved in the spring period under the condition of cultivation on MS media with the addition of 0.25-0.5 mg/l 6- (furfurylamino) purine (kinetin) and activated carbon 1-2 g/l.

In the autumn period, a significant decrease in the regenerative ability of microshoots were observed on all studied medium variants, which was demonstrated by a decreasing in the monthly average amount of growth and the number of internode formed.

In the winter period, yellowing of individual leaves was noted with their subsequent fall, while the base of the microbusiness acquired dark pigmentation. Antioxidants and a frequent subculture for fresh nutrients were used to stabilize the growth of microwaves (the cultivation cycle was 3-5 days), as well as alternating hormonal and non-hormonal media.

Conclusion

The mature trees are of great importance for providing a complex of ecosystem services, among which the most important are recreational and biodiversity conservation. Data on the

ecosystem of the role of centuries-old trees are very limited and do not allow to form a full-fledged view of the ecological value of such representatives of the plant world.

In result, was determined that organogenesis in culture of mature oaks depend on the range of factors such as: the type of primary shoots of the donor plant, originating on the first stages and influence the exogenous balance of growth regulators, and consequently, the response to the evaluated morphogenic processes, the phonological phase, the quantitative and qualitative ratio of growth regulators in the medium, influence of the genotype. Also, has been mention that the juvenile explants have more ability to indirect morphogenesis in the early stages of reproduction.

Development of new methods involves needs for an individual selection of nutrient medium for the cultivation of different explants at every subsequent stage of reproduction.

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Remote Environmental Monitoring of the Mining and Chemical Enterprise Territory at the Stage of Liquidation

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Abstract – The negative ecological changes of the territory of Rozdil State Mining and Chemical Enterprise "Sirka", which is in liquidation, have been analyzed using satellite images. It is established that environmental monitoring should be carried out at all stages of liquidation.

Keywords – liquidation state, environmental monitoring, environmental changes, mining, soil pollution, water pollution, remote environmental monitoring.

Introduction

The long-term extraction of minerals in the territory of Ukraine has led to high levels of contamination of soil, surface and groundwater, and the formation of large volumes of waste. The development of sulfur deposits harms the state of the environment and worsens the living conditions of the population in the mining regions [1].

Liquidation Problems

Only in Lviv region there are non-liquidated quarries, mine voids, waste heaps and chemical wastes, non-solved issues about the liquidation and reclamation of disturbed land after activity of Yavoriv State Mining and Chemical Enterprise (SMCE) “Sirka”, Rozdil SMCE “Sirka”, State Economic and Settlement Enterprise “Podorozhnenskyi Rudnyk”, and Stebnyk SMCE “Polimineral”. Due to more than 150 years of exploitation of the Boryslav oil and gas field, a difficult ecological situation in Boryslav is connected with gas pollution, soil, groundwater and surface water pollution [2].

Environmental Monitoring Using Satellite Images

The monitoring and control of the territory of a mining and chemical enterprise state at the liquidation stage should be complex and carried out at all its stages.

Current global trends in space technology indicate that Earth remote sensing is one of the most important areas. The use of digital space imagery technology enables the full or partial digital data stream of Earth remote sensing [3].

Using the data of site https://earthengine.google.com/timelapse/ cosmograms of the territory of Rozdil SMCE “Sirka” from 1985 to 2018 were taken, and we analyzed the natural state and negative ecological changes of the study area in connection with anthropogenic action (Figure).

Lake Serednie began to form in 1989 as can be seen from the satellite images. Lake Chyste began to form in 1997, and Lake Hlyboke – in 2003. The flood level of Lake Hlyboke reached 252.4 m in 2009.

By analyzing satellite images it is determined that the area of lump sulfur residues has decreased significantly over the last 12 years.

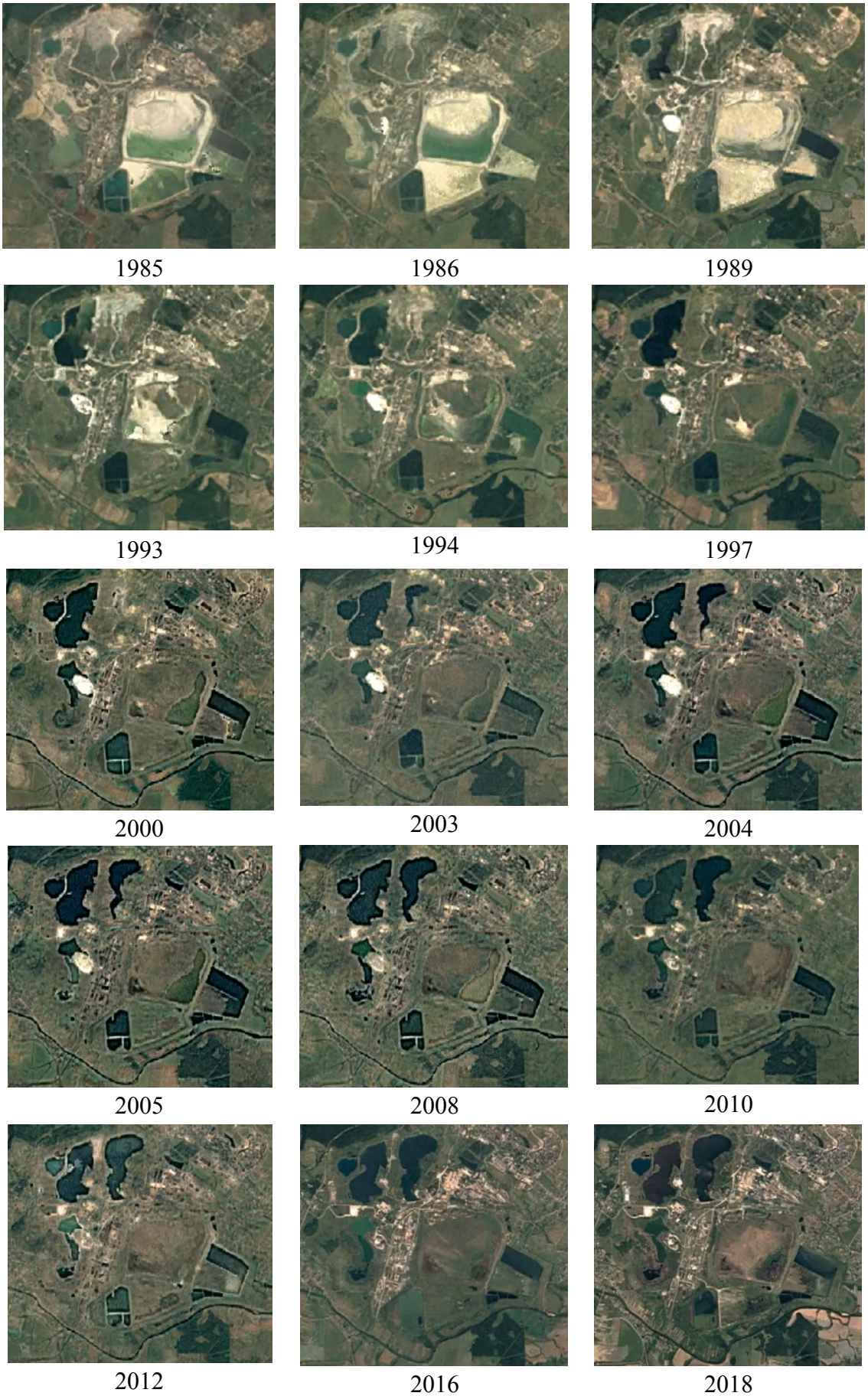

Figure. Satellite Images of Rozdil SMCE "Sirka"

In addition to the geophysical changes in the main sources of danger, there are also negative changes in the chemical composition of soils and water on the territory of the enterprise.

According to the data, in the surface water layer of all the Rozdil lakes, the excess of normative indicators for mineralization (MPC – 1000 mg/m^3) and sulfates (MPC – 100 mg/m^3) are recorded and in the Lake Kysle and Lake Serednie are the excess of MPC by phosphates (MPC – 0 mg / m^3), in the lake. The pH in Lake Kysle is 5.25 in the norm from 6.5 to 8.5 (Table). There is also MPC excess of heavy metals in the soil by the following elements: Sr, As.

Table

Results of the hydrochemical monitoring

Indicator	Actual concentrations, mg/dm^3				
	Lake Serednie	Lake Chyste	Lake Kysle	Lake Hlyboke	Chanel Lake Hlyboke-Dniester
pH	7.65	7.65	5.25	7.3	6.05
Sulfates	1755.8	1044.2	1200.8	1628.6	1665.3
Chlorides	241.4	63.2	113.8	122.4	–
Mineralization	3019.5	1684.9	2701.4	2502.4	2498.6
Ammonium nitrogen	5.2	0.9	6.9	2.8	4.6
Nitrate ions	1.8	0.5	6.9	0.4	–
Phosphates	1.1	0	729.3	0	–

Conclusion

The negative ecological changes of the territory of Rozdil State Mining and Chemical Enterprise “Sirka”, which is under liquidation, have been analyzed using satellite images. In addition to geophysical changes in the main sources of danger, there are also negative changes in the chemical composition of soils and water.

It is established that environmental monitoring should be carried out at all stages of liquidation.

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Improving the dynamics of plant growth by compatible applying of spent zeolite and mycorrhiza fungus

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Abstract – To purify wastewaters, milk processing plants use different methods, but the sorption method is the most affordable and effective. Among the various types of adsorbents, natural zeolites that have adsorptive and ion-exchange properties deserve special attention, which makes them attractive for use in agriculture as a soil amendment. It has been proved that the co-application of spent zeolite with the components of wastewater of the dairy industry and mycorrhizal inoculation makes it possible to increase the yield of agricultural crops by about twice.

Keywords – zeolite, mycorrhiza, supplementary fertilizing, plants, regression analysis

Introduction

With the advance of modern production, in terms of its scale and rates of growth, the problems of the development and implementation of low-waste and non-waste technologies become more and more relevant. Addressing these problems as soon as possible is considered in a number of countries as a strategic direction for the rational use of natural resources and environmental protection [1-3]. To purify the wastewater, milk processing plants use different methods, but the most affordable and effective are sorption methods which are characterized by high efficiency and cheapness. Among various types of adsorbents, natural zeolites that have adsorptive and ion-exchange properties deserve special attention [3-5].

Zeolite has many unique properties, which makes it attractive for use in agriculture as a soil improver. For this purpose, it is widely used in Japan, the USA, Bulgaria, Hungary, and Poland. Zeolite perfectly aerates the soil, promotes the development of root systems and the growth of the whole plant; holds enough water in the root zone – 40-70%, works as a storage tank for fertilizers – nitrates, phosphates, potassium, nutrients, essential components for plant's health and its growth. Zeolite sorbs fertilizers with its branched structure until plant roots absorb them. Nitrogen, detained in zeolite, is not soluble in water, and is not washed away by rain for a long period of time. Thus, less fertilizers, especially nitrogen, are washed away with groundwater. Zeolite not being used,, about 35% of nitrogen is washed out of the root zone and enters the groundwater contaminating it with nitrates and nitrites [3]. This sorbent can be used both in combination with mineral and organic fertilizers and as the spent product after treatment of milk-processing wastewater.

Symbiosis of plants and fungi has existed since the creation of the world and contributes to a great variety of life forms on Earth. This phenomenon was discovered by German scientists in 1845. Mycorrhiza improves soil quality, aeration, porosity, and the volume of the total absorbing surface of the plant root is increased by a thousand times. An effective factor that will make it possible to change the kinetics of agricultural crop growth and increase their yield is the use of spent zeolites after the treatment of wastewaters in milk-processing industry, in combination with agents based on the symbiotic fungi that form mycorrhiza with the plant [5].

To confirm the benefits of zeolite and mycorrhiza in the soil and their interconnection, vegetation studies were carried out that reproduced the real-life conditions of cultivating crops. In the experiment, simulated were the modes of extra nutrition and watering that are practiced in greenhouse facility.

To grow vegetables, you need 10-22 kg of zeolite per m2 , so this area of land, which amounts to 0.02 m2 of soil, requires 0.4 g of extra nutrition. Adsorption capacity of sorbent for lactic acid a * lactic acid = 0.12 g / g of ads. Thus, the sorbent after the sorption process contains in its composition 0.12 g of fertilizer (lactic acid) in 1 g of sorbent.

To investigate the efficacy of the combined application of spent zeolite together with the components of wastewaters in milk-processing industry and the effect of mycorrhizal inoculation on the plant growth kinetics, five consecutive parallel experiments were set up: pure soil without adding fertilizers of other components; soil with the addition of mycorrhiza (65,000 spores) and +10 g of natural zeolite; soil with the addition of mycorrhiza (65,000 spores) and +10 g of spent zeolite; soil with the addition of mycorrhiza (65,000 spores) and +20 g of natural zeolite; soil with the addition of mycorrhiza (65,000 spores) and +20 g of spent zeolite.

Seeds of garden-cress, which is a biotest plant, were sown in a container (50 seeds in each container). Garden-cress, as a bioindicator of soil contamination testing, is convenient to use since the sprouts can be seen when being 3 days old, and conclusions can be made as early as10 days later. During the growing season, the plants were taken care of and monitored (soil loosening, watering (100 ml))

When analyzing the germination and condition of plants during the growing season and their condition in the end, we observed that there was retarded germination and stagnation of the plants grown without combined application of spent zeolite and agents based on mycorrhiza as compared to other plants treated with spent zeolite and myccorrhiza-based agents. There was obviously a better development of plants in mycorrhizal soil fertilized with 10 and 20 grams of the spent sorbent which was introduced into the soil prior to sowing.

On the fourth day after the combined application of spent zeolite with components of wastewaters of milk-processing plants together with mycorrhizal inoculation, the substrate got cracked, which suggests the germination of the sown seeds. The plants fertilized with 10 g of spent sorbent and with mycorrhizal inoculation began to germinate and as of this day their quantity was 15%. The fertilization with 20 g of spent sorbent gave at that time their emergence of 70%. On the 5th day began germinating the plants that had not been treated, as well as those that had received the natural form of zeolite. On the eighth day of the study, it was evident that the plants that had been inoculated with mycorrhiza and had been fertilized with natural zeolite reached a height of 1.5 cm. Their quantity as of that day was ~ 50%. The germination of plants whose soil had been fertilized with a spent form of zeolite and with mycorrhiza was 90%. The difference in the amount of nutrients in the substrate gave a noticeably better result in the plant growth. The plants that had received 10 g of spent sorbent and the spores of symbiotic fungi reached a height of 3 cm, 4 cm – fertilization with 20 g of the same zeolite compound and spores of the micorrhiza1 agent.

The germination of plants in the containers with mycorrhizal soil and with the addition of natural zeolite lasted until the 13th day and reached ~ 78%. It is worth noting that we achieved this result with the addition of 20 g of spent zeolite to soil with mycorrhizal spores as early as on the 4th day of the study. Also noticeable is the retarded growth of those plants that reached a

height of about 4 cm in the final state and a lower development of plant germination density due to the limited ability to consume trace elements by the plant.

The plants that had been fertilized with 20 g of spent sorbent reached a height of 6-7 cm. Reducing the dose of this fertilizer to 10 g resulted in down growth of the plants, on average, up to 5-6 cm. The difference in the amount of the added spent zeolite with the components of wastewaters of milk-processing plants also somewhat affected the development of plant biomass due to the lack of nutrition elements for them.

We set out to investigate what factors contribute to the growth and development of agricultural crops, and time dependence of the height of the garden cress during the growing season is shown in Fig. 1

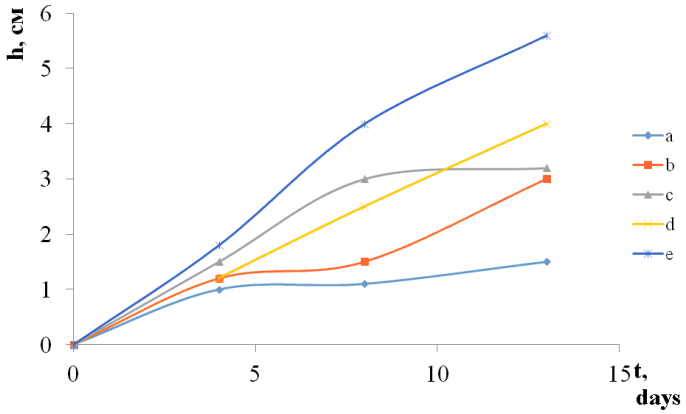

Fig. 1. The dependence of the height of the garden cress on the timepoint of the growing season: a) pure soil; b) soil with the addition of mycorrhiza (65,000 spores) and +10 g of natural zeolite; c) soil with the addition of mycorrhiza (65,000 spores) and + 10 g of spent zeolite; d) soil with the addition of mycorrhiza (65,000 spores) and +20 g of natural zeolite; e) soil with the addition of mycorrhiza (65,000 spores) and +20 g of spent zeolite.

Consequently, as a result of the analysis, we concluded that the most important factor affecting the kinetics of plant growth is" soil with the addition of mycorrhiza (65,000 spores) and + 10 g of spent zeolite, and the soil with the addition of mycorrhiza (65,000 spores) and +20 g of spent zeolite". Other factors that play a prominent role in improving the kinetics of plant growth are" soil with the addition of mycorrhiza (65,000 spores) and +10 g of natural zeolite, and soil with the addition of mycorrhiza (65,000 spores) and +20 g of natural zeolite, and the amount of germinated seeds, pcs. At the same time, the indicators such as "amount of water for watering plants, ml, and plant weight, g" has little effect on plant growth kinetics.

In the final stage of the studies, the plants are collected and dried to obtain the total weight of sprout material. This was done in order to more accurately show the difference in the germination of garden cress plants.

Table 1

Comparison of the obtained weight of plants grown with the application of nutritional components to the substrate

No.	The name of the added component	Plant weight, g
1	without fertilizer application	0.051
2	mycorrhiza (65,000 spores) and +10 g of natural zeolite	0.04
3	mycorrhiza (65,000 spores) and +10 g of spent zeolite	0.085
4	mycorrhiza (65,000 spores) and +20 g of natural zeolite	0.092
5	mycorrhiza (65,000 spores) and +20 g of spent zeolite	0.1

Analyzing the data in Table 1, we can see that the weight of plants that were grown with the application of 10 and 20 grams of the spent sorbent and the 65,000 spores of mycorrhiza, was approximately twice as much as the weight of plants grown without fertilization. Consequently, based on the data obtained during the vegetation studies, we can propose the application of the spent sorbent, obtained in the process of treating wastewaters of milk-processing plants + inoculation with mycorrhiza, for fertilizing agricultural crops.

Conclusion

Consequently, as a result of the study, the authors obtained the following results: developed and implemented was the algorithm of integrated evaluation of the effectiveness of combined application of zeolite and various doses of the same mineral in the form of a spent sorbent which was obtained as a result of treating wastewaters in milk-processing plants + agents based on mycorrhizal fungi associated with plant microorganisms; It was found that the strongest influence on the plant growth kinetics is exerted by: soil with the addition of mycorrhiza (65,000 spores) and +10 g of natural zeolite; soil with the addition of mycorrhiza (65,000 spores) and + 10 g of spent zeolite; soil with the addition of mycorrhiza (65,000 spores) and +20 g of natural zeolite; soil with the addition of mycorrhiza (65,000 spores) and +20 g of spent zeolite; It was defined that the construction of an integrated multifactorial model provides the basis for further studies on the evaluation of combined or single application of zeolite and various doses of the same mineral in the form of a spent sorbent which was obtained as a result of treating wastewaters in milk-processing + agents based on mycorrhizal fungi associated with plant microorganisms.

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Man-Made Wastes – Basis For Biological Reclamation

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Abstract – the paper presents the research of hypothesis testing on the possibility of using man-made waste such as sewage sludge as a component of the substrate for biological reclamation. The results make it possible to determine the composition of the substrate for optimum plant growth using the maximum amount of waste.

Keywords – sewage sludge, utilization, sorbents, soil, bioindication

Introduction

Nowadays creation and accumulation of wastes is one of the biggest environmental problems. A lot attention is being paid to wastes that are created during production and consumption processes, particularly man-made wastes. One of a most widespread type of waste is large-scale sewage sludge that is created after phase of wastewater biological treatment.

Every year volume of sewage sludge increases and available sludge sites aren`t capable of accepting whole volume, that is why great land area, which is being used for waste disposal, is constantly increasing, hence it is a great harm for the environment and future usage of the land that is covered by such landfill is not possible [1]. Unfortunately, ecological problem of utilization of sewage sludge, obtained from municipal wastewaters that in large numbers are created in modern cities from floating sewer system remains to be unsolved. The most perspective technologies are burning and using ash in building industry, but currently this process requires consistent energy and financial expenses (45 €/ton) [2]. Given technology is being planned to launch at Bortnytska aeration plant (before 2025, Kyiv) and will be able to solve problem with only future sludge accumulations.

In well developed countries of Europe and the USA around 30% of such municipal sewage sludge are utilized [3], and in Ukraine – not more than 4–5%. From technological and economic approaches majority of pollution control facilities in Ukraine are incapable of utilizing sewage sludge from communal household wastewaters. Being accumulated at filtration fields these wastes cause dangerous environmental situations near the pollution control facilities. At the same time chemical composition of sewage sludge can be potentially used as fertilizer and it also appears to be great substrate for biogas production [4]. This is why effective solution of these wastes' utilization problem requires conducting intense environmental and agrochemical studies.

Very perspective method of using sewage sludge is digestion in order to obtain biogas. This provides a possibility to remove all organic compounds and use mineral compounds as fertilizer. It is worth mentioning that sewage sludge (active sludge) under efficient treatment contains enough quantity of biogenic elements necessary for growth and development of the plant.

It is known that in average sewage sludge contains 174000 mg/kg^{-1} organic carbon (C), 17700 mg/kg^{-1} – general nitrogen (N) and 13350 mg/kg^{-1} – general phosphorus (P), what allows to use it for production of organic and mineral fertilizers with further usage in agriculture [5-7]. Apart from that sewage sludge are also being used for reclamation of lands, quarries and closed landfills, production of building materials, obtaining energy etc. [8-10].

Considering the aforementioned, with the help of sewage sludge it is possible to solve not only environmental but economic problems concerning supply of raw materials and mineral resources not only in Ukraine, but in the whole world.

In our work we suggest using mixture of man-made wastes with additives for creating substrate which can be used for biological reclamation of damaged lands.

Materials and methods

Our primary task for creating substrate was conducting quality analysis of sludges after wastewater biological treatment. For this purpose, the sewage sludge was collected from the Lviv municipal wastewater treatment plants (LMWTP) and analyzed in the certified laboratory in the Lviv branch of the State institute «Soil protection institute of Ukraine».

After quality analysis it was necessary to form appropriate composition from wastes and other components, which could create conditions for safe development of plant and facilitate stability of the system.

That is why for testing composition of the substrate we have conducted bioindication according to State standards DSTU ISO 11269-1:2004 and 11269-2:2002. Comparison of growth substrate was carried in accordance with control dark grey podzol soil. For bioindication the following plants were used: common barley (*Hordeum vulgare*), white mustard (*Sinapis alba*) and cress-salad (*Lepidium sativum*).

The research was carried out in four stages:

Stage 1: two experiments were carried out. During first experiment settled sewage sludge and soil were mixed in the following ratio (%): 100:0; 80:20; 60:40; 40:60; 20:80; 0:100. In Petri dishes seeds of barley, white mustard and cress-salad were planted on the created substrate. Experiments were carried out fourfold. During second experiment mixture of settled sewage sludge + soil and thermally processed sewage sludge (2 hours under t=105°C) + soil, under the following ratio (%): 60:40; 20:80; 0:100 were used. Bioindication was conducted in Petri dishes with planting seeds of barley into substrate from thermally processed sewage sludge, and seeds of barley that was etched with the help of Vitawax 200 FF. Experiments were carried out threefold.

Stage 2: experiments were carried out with the help of fresh sewage sludge with adding dark grey podzol soil under the following ratio (%): 100:0; 80:20; 60:40; 40:60; 20:80; 0:100. In Petri dishes seeds of barley, etched barley (Vitawax 200 FF) and cress-salad were planted. Experiments were carried out fourfold.

Stage 3: experiments were carried out with the help of fresh sewage sludge that were added into dark grey podzol soil in the following quantities (%): 0; 20; 25; 30; 35; 40. In Petri dishes sorbent was added to substrate in the following quantities (%): 0; 5; 7,5; 10 and planted seeds of barley. Experiments were carried out threefold.

Stage 4: dark grey soil was mixed with sewage sludge, empty rocks from spoil tips and sorbent under the following ratio (%): 30:30:30:10, and also were mixed sewage sludge, empty rocks and sorbent in the following ratio (%): 45:45:10. Bioindication was carried out with the help of barley. Threefold frequency.

During the studies observations were conducted on the following indicators: time of appearance of sprouts, their number per day, total germination. At the end of the study the length and weight of aerial parts and roots were measured.

Results and discussion

Primary studies on quality composition of sewage sludge after biological treatment of wastewater from LMWTP were carried out in certified laboratory of Lviv branch of the State institute «Soil protection institute of Ukraine». In the result of quality composition of sewage

sludge presence of main biogenic elements was defined (N – 3,56, P – 1.6, K – 0.3 %), macro- and microelements (Mn –45,1, Fe – 65,0, B – 4,01 mg/kg), content of organic matter (23,8 %), content of moving forms of heavy metals in studied samples did not exceed MPC (Cu – 4,0, Zn -17,6, Co – 2,86, Pb – 1,56, Cd – 0,20, mg/kg), neutral reaction of acidity of the medium (pH=6,4). More detailed description of quality composition can be found in the work [11]. Obtained results of quality sewage sludge indicates their relatively safe composition for using as substrate.

For carrying out studies we used two types of sewage sludge:

- settled – sewage sludge after biological treatment of wastewater that were hermetically kept during 6 months for imitation of accumulation process on sludge sites;
- fresh – sewage sludge that after wastewater biological treatment were sampled from municipal wastewater treatment plant and were not kept during 1-3 days.

Results from the experimental studies that were carried out at **Stage 1:**

- even small amount of wastewater settled sewage sludge (20%) in substrate composition negatively affects plants (Fig. 1);
- pathogenic microflora and fungi did not enable growing all three plants that were used for bioindication (barley, white mustard and cress-salad);
- usage of thermally processed substrate (2 hours under t=105°C) did not give any result, quantity of microflora reduced only at primary stage;
- usage of mordant (Vitawax 200 FF) also did not give any positive results, growth was not identified.

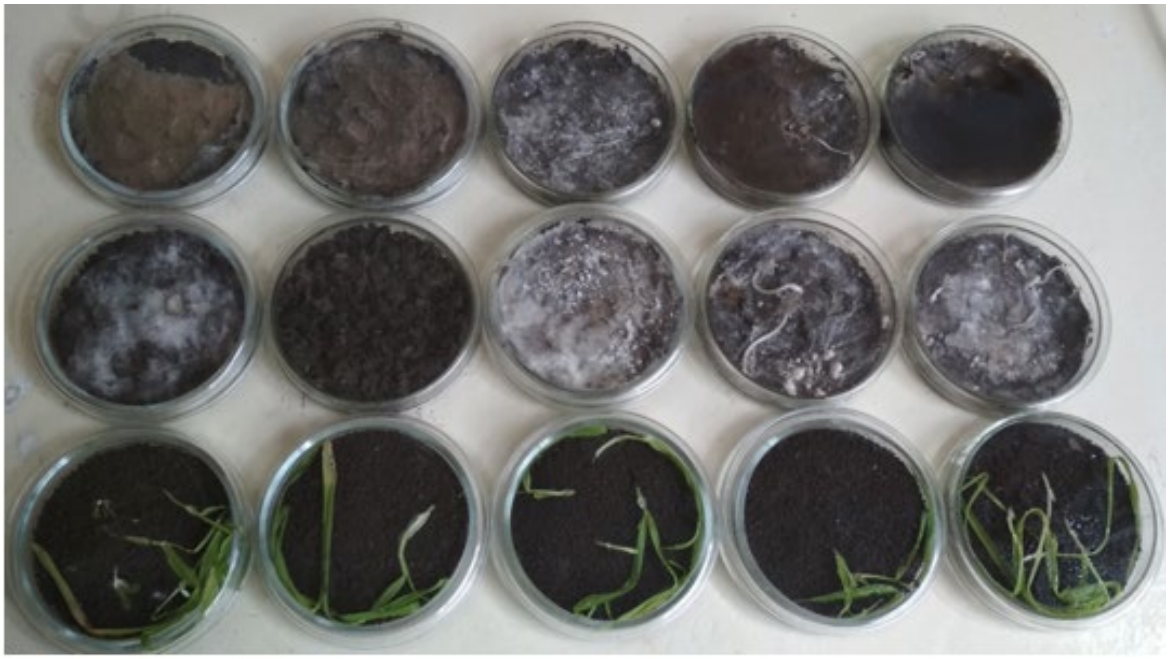

Fig. 1. Presence of fungi and pathogenic microflora in **Stage 1** samples

So, it is possible to conclude that sewage sludge under such type of preservation contains considerable amount of fungi and pathogenic microflora which is a big problem.

Studies carried out during **Stage 2** on fresh sewage sludge are illustrated in Fig. 2. In cases where amount of sewage sludge exceeded 40 % of plants germination, bioindicators were not identified, which is why such substrates were not illustrated in graphic.

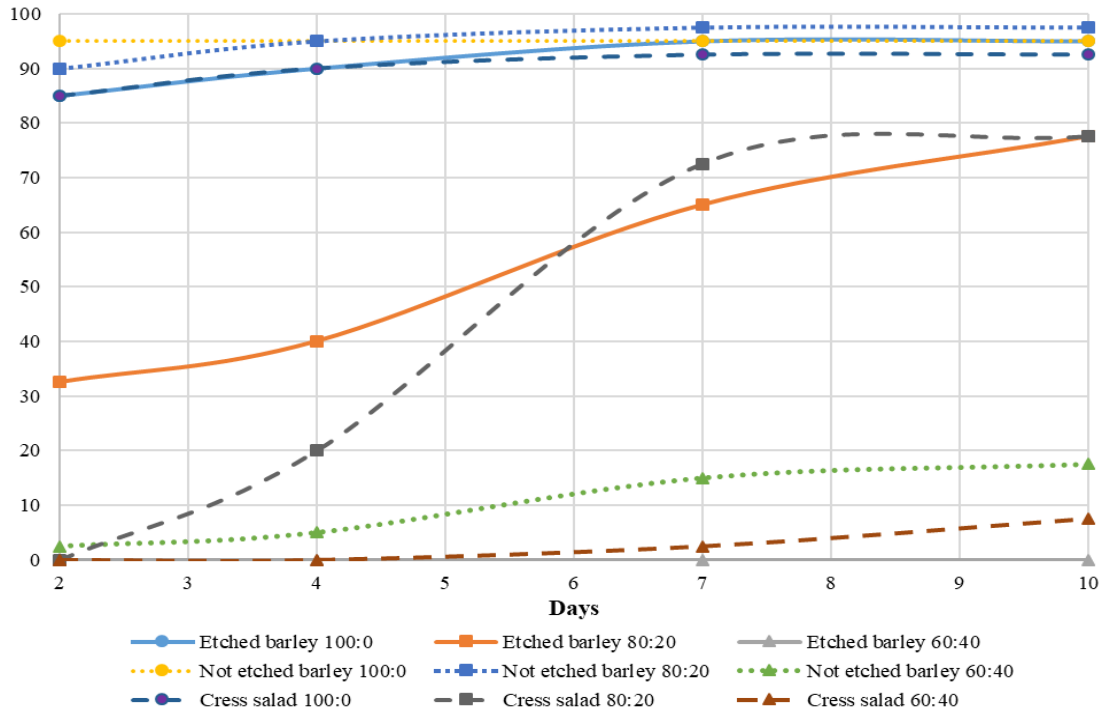

Fig. 2. Dependence of germination of bioindicators plants on time and substrate plants (**Stage 2**), %

So results of **Stage 2** experiments indicate possibility of using fresh sewage sludge in composition for creating substrate in quantity of ≈ 20% since quantity of germinations at the final stage of experiment did not differ considerably from control (etched barley – 17,5%, cress-salad – 15%), but in the studied substrates a delay was observed in occurrence of plants over first 7 days of the experiment. Adding 40 % of wastewater sewage sludge into substrate negatively affected all studied experiments.

Experiment carried out at **Stage 3** tested opportunity of adding sorbents (0-10 %) into the composition for improvement of substrate facilities. During previous experimental studies maximum 40% of sewage sludge were added to this substrate and barley (*Hordeum vulgare*) was used as plant for bioindication.

Results of **Stage 3** experiments are illustrated in Fig. 3. In the figure main parameters that were calculated at 10th day of the experiment are shown.

In cases where there were 40% of sewage sludge without adding sorbent average germination was 23 %, and in cases where 40 % of sewage sludge were added and 7,5 % of sorbents the germination reached 83,33 %. Also, almost in all cases where mixture of sewage sludge and sorbents was used, better growth was identified of terrestrial part of the plant with the increase of sewage sludge part in the substrate.

So, results obtained from **Stage 3** experiments indicate that it is necessary to add into substrate composition sorbents, and this gives an opportunity to increase part of sewage sludge to 40 %, and possibly to even more harmlessly for plants.

Studies at **Stage 4** were concentrated on adding another part of man-made wastes such as – empty rock that is layered on boney piles. However, the study did not give positive result under given ratio (soil + sewage sludge + empty rock + sorbent (%): 30:30:30:10, and also sewage sludge + empty rock + sorbent (%): 45:45:10) germination of plant-bioindicators almost did not take place.

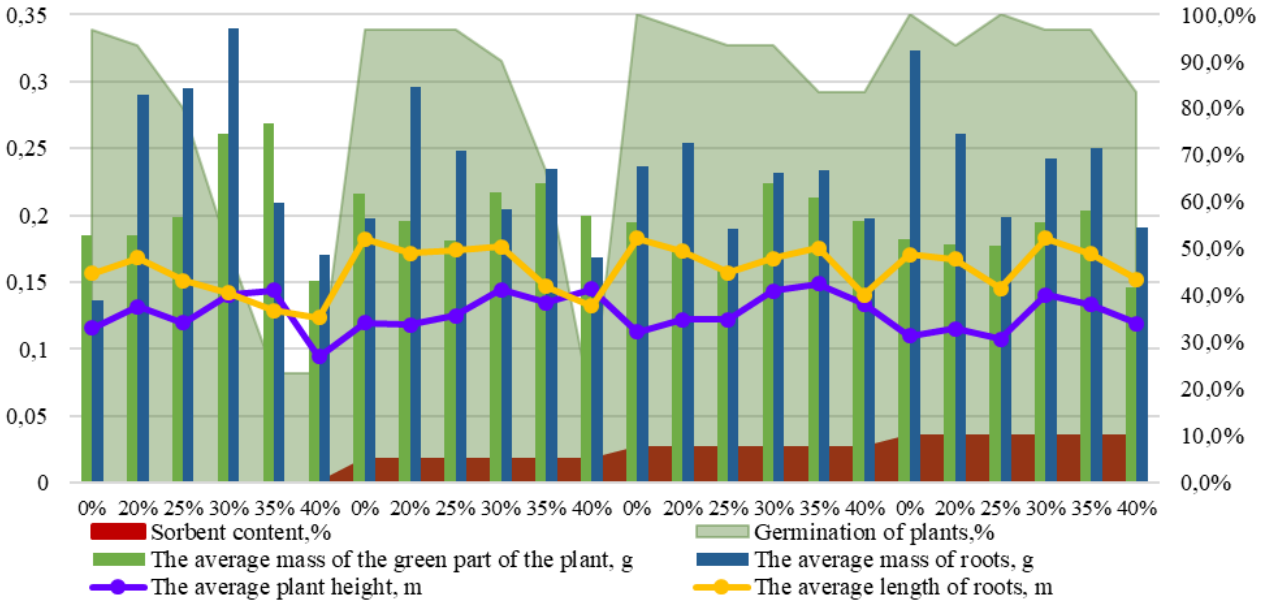

Fig. 3. Development of plants-bioindicators depending on substrate composition (Stage 3)

So, it is necessary to study more the possibility to use empty rock in substrate composition, to define its quality composition and also to reduce its part in the substrate.

Conclusion

Summing up our conducted research, we can conclude that it is inefficient to use settled sewage sludge as substrate, unless disinfected it. However fresh sewage sludge shows considerably better results, particularly when adding natural sorbents to the composition. Also, it is important to note that at initial stages the sewage sludge can speed down plant`s growth, but in the future, it affects the plant`s growth as well as the growth of bioindication plants positively.

Thus, with every stage of research we improve substrate for biological reclamation for industrially damaged lands. Using man-made wastes, sewage sludge after biological treatment of wastewaters from Lviv municipal wastewater treatment plants allows to reduce price of reclamation process and its hazardous impact on the environment.

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