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Lubomyr SIKORA, Nataliia LYSA, Olga FEDEVYCH
Lviv Polytechnic National University, Lviv, Ukraine
Rostyslav TKACHUK
Lviv State University of Life Safety, Lviv, Ukraine

LASER AND INFORMATION TECHNOLOGIES FOR CONTROLLING DYNAMIC DISPLACEMENTS SPATIAL STRUCTURES OF OBJECTS UNDER THE INFLUENCE OF ACTIVE MAN-MADE AND NATURAL RISK FACTORS FOR ACCIDENTS

At the present stage of science development, for technological and technogenic energy-intensive systems, systematic methods of identification of structure, dynamics, and risk assessment are developed, while for spatial objects this problem is not fully solved. This applies to the construction and operation of such objects with a spatially distributed structure such as bridges, large pavilions, high-rise buildings, aggregate lines on a common foundation for color printing, which are subject to a large dynamic, non-uniform load-capacity, operating over a long period of operation. Their destruction with the combined action of dynamic and static heterogeneous flow factors in time of high power, leads to the accidents and human losses. The main factor that leads to cognitive errors in the design of spatial structures is that experts in the design process do not fully take into account the concepts of physical force, power and physical energy factors with stream random structure. In this aspect, the problem of dynamic structural stability under the influence of factors with a stochastic structure drew attention to Y. P. Dragan, introducing the notion of "stochastic process of finite energy" and "finite power of flows (sequences) of active physical force actions". Under certain conditions, the complex action of force factors leads to the emergence of solitons, that is, the formation of the peak of energy and power at a certain time in the weakest node of the structure that destroys it. If the designer, by virtue of his cognitive abilities and level of knowledge, does not take into account the energetic nature of the factors as destructive forces, then this leads to the destruction of infrastructure objects (cities in Genoa, Italy 2015, built in 1967) devastating floods, fires, transport disasters, tsunami. As for the steel construction bridges in the USA (New York), built on the basis of the methods of vibration calculations by S. Tymoshenko, they are operated for more than 100 years, with appropriate technical service.

The assessment of the vibrational stability of spatial structures, both existing and new projects, remains a complex control problem that is not resolved to the fullest, and therefore the development of integrated intellectual methods for designing and controlling their state is relevant

The intensive development of infrastructure, both social and technogenic, results from the impact of transport flows, power plants, harmful emissions, to the growth of force environmental load on spatial structures, corrosion of metal components, and the growth of vibrational effects on elements of objects. Further development of such negative processes leads to a decrease in the strength of structures, their stability, operational reliability and destruction. Reducing the quality of bearing structures, due to neglected negative influences, makes it impossible to forecast the moment of emergency situations. Accordingly, the development of methods for remote control of vibrations of spatial elements of bearing structures is a main problem for various industries.

Key words: construction, vibration, laser, signal, dynamic processes, active factors, data, system, information, project, risks, accident.

ЛЮБОМИР СІКОРА, НАТАЛЯ ЛИСА, ОЛЬГА ФЕДЕВИЧ
Національний університет «Львівська політехніка»
РОСТИСЛАВ ТКАЧУК
Львівський державний університет безпеки життєдіяльності

ЛАЗЕРНІ ТА ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ КОНТРОЛЮ ДИНАМІЧНИХ ЗМІЩЕНЬ ПРОСТОРОВИХ СТРУКТУР ОБ'ЄКТІВ ПІД ВПЛИВОМ АКТИВНИХ ТЕХНОГЕННИХ ТА ПРИРОДНИХ ФАКТОРІВ

На сучасному етапі розвитку науки, для технологічних і техногенних енергоактивних систем, вироблені системні методи ідентифікації структури, динаміки, оцінки ризику, тоді як для просторових об'єктів ця проблема в повній мірі не розв'язана. Це стосується будівництва і експлуатації таких об'єктів з просторово розподіленою структурою як мости, великі павільйони, висотні будинки, агрегатні лінії на спільному фундаменті для кольорового друку які піддаються великим динамічним неоднорідним по потужності навантаженням, що діють протягом тривалого часу експлуатації. Їх руйнація при сукупній дії динамічних і статичних неоднорідних потокових у часі факторів великої енергетичної потужності, приводить до аварій і людських втрат. Основний фактор, який приводить до когнітивних помилок при проектуванні просторових конструкцій, є те що фахівці у процесі розробки проекту не до кінця враховують поняття фізичної сили, енергії потужності та фізичної енергії факторів з потоковою випадковою структурою. На цей аспект проблеми динамічної стійкості конструкції при дії факторів з стохастичною структурою звернув увагу Я. П. Драган, ввівши поняття «стохастичного процесу скінченої енергії» і «скінченої потужності потоків (послідовностей) активних фізичних силових дій». При певних умовах комплексна дія силових факторів приводить до виникнення солітонів тобто формування піку енергії та потужності у певний момент часу у найслабшому вузлі конструкції, що її руйнує.

Якщо проектант, в силу своїх когнітивних здібностей і рівня знань, не враховує енергетичну сутність факторів, як руйнівних сил, тоді це приводить до руйнування інфраструктурних об'єктів (міст в Генуї, Італія 2018р., збудований у 1967 році, Китай 2019р.) руйнівні повені, пожари, транспортні катастрофи, цунамі. Щодо мостів з металоконструкцій в США (Нью-Йорк), побудованих з врахування методів вібраційних розрахунків С. Тимошенко, то вони експлуатуються більше ніж 100 років, при відповідному технічному обслуговуванні.

Оцінка вібраційної стійкості просторових конструкцій, як існуючих так і нових проектів залишається складною проблемою створення систем контролю і діагностики, нерозв'язаною у повній мірі, і тому розроблення інтегрованих *інтелектуальних методів проектування систем контролю методом дистанційного лазерного зондування є актуальною.*

Ключові слова: конструкція, вібрація, лазер, сигнал, динамічні процеси, активні фактори, дані, система, інформація, проект, ризики, аварія.

Introduction

Intensive development of infrastructure, both social and man-made, leads, due to the action of transport flows, power plants, industries with harmful emissions, to an increase in environmental environmental load on spatial structures, corrosion of metal components, increased vibration effects on elements. Further development of such negative processes leads to a decrease in the strength of structures, their stability, operational reliability and destruction. The decline in the quality of load-bearing structures, due to unaccounted for negative impacts, makes it impossible to predict the moment of occurrence of emergencies. Accordingly, the development of methods for remote control of vibrations of the spatial elements of load-bearing structures is an urgent problem for various industries.

Analysis of literature sources

The problem of monitoring and assessing the stability of spatial structures is relevant in recent centuries (1700-2019). It includes problems of building destruction, vehicles, communications, large bridges, high-rise buildings [1] under the influence of various factors [2-3], vibration [4-7], soil landslides and earthquakes [8], aging of components and materials[9] dynamic transport loads and flows [10]. One of the least studied are cognitive factors and deficiencies as well as errors occured in the design process [11-14] and subsequent operation with the participation of operational personnel and designers [15-16].

Therefore, the methods and tools development – both cognitive control of projects and vibration control systems of complex spatial structures is still relevant [17-18], as it requires an integrated approach using signal theory [19-20], the theory of data processing [21-22], interpretation of data and situations, decision making [4, 23-25].

Accordingly, an important task is the construction of objects models and simulation modeling on analogues [24, 26], which ensures the detection of new physical effects [27]. Without taking into account the peculiarities of cognitive thinking of designers, it is impossible to reliably design buildings and their implementation with the appropriate service life and resistance to destruction [28-32].

Introduction. Analysis of dynamic control problems

At the present stage of information and measuring systems development for vibration control of complex structures under the action of a set of energy-active factors by non-contact remote method is not fully considered.

Therefore, the development of laser methods for remote control of dynamic modes of large spatial structures, under the influence of active dynamic factors in time and space is an important problem.

The purpose of the study. To control the vibration of spatial structures and aggregate production systems to create and justify the use of laser probing and develop a block diagram of a laser vibrometer.

Basic tasks to be solved

To solve the problem of remote control of vibration of large spatial structures and aggregate printing systems it is necessary:

– to substantiate structural models of objects and behavior models in time under the influence of active factors;

– to justify the choice of laser remote sensing method for controlling the vibration of structures in critical places of the object of study and the spatial structure of the object structures and (foundation) platform of aggregate production lines of high quality products;

– to develop information technology of laser signals processing and their estimation for determination of vibration parameters.

Research methods

To solve a complex scientific and applied problem of creating systems for remote control of vibration load of spatial structures and boundary modes on the basis of laser sounding, methods and theories were used:

Models of dynamic factors influencing spatial structure.

Since dynamic factors [6, 9, 33] have an energy-active structure, then ignoring their essence leads to the collapse of the mechanical spatial structure due to oscillations and soliton effects [5].

Accordingly, the study of their dynamics requires the use and creation of new methods and control systems based on laser remote sensing, which provided the detection of oscillations of the spatial structure of structures [34]. To solve the above problems, needed:

1. Model of n – dimensional spatial fluctuations for a long section of the bridge (100 m) and a common foundation for aggregate printing production.

2. Energy soliton model for oncoming traffic flows as perturbing factors. $\left(\xrightarrow{\vec{\mathrm{n}}^2} \uparrow \vec{n}_n\right)$ vertically and along relative to the supports (Fig. 1).

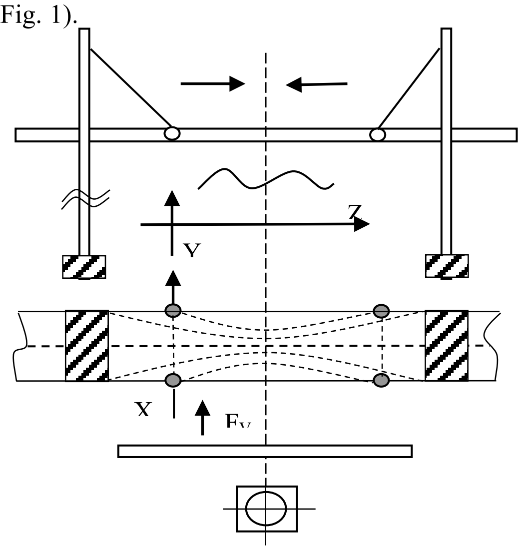

Fig. 1. Method of laser sounding of spatial structure

3. The model of wind load with variable speed as a factor of perturbation of transverse oscillations.
4. Transport flows as excitatory factors with a continuous and discrete structure (homogeneous, heterogeneous, group (unilateral, counter)).

$$TS_1^d = \{(m_i, V_i)\}_{Tn},$$

$$T\mathrm{S}_2^{\mathrm{d}} = \left\{\sum_{i=1}^{K}\left(m_j, V_j\right)_{ti}\left(t_i \in T_n\right)\right\}, \text{ at the same time } \sum_{i=1}^{\mathrm{n}} \mathrm{m}_{\mathrm{i}} \le M_d$$

where $T\mathrm{S}_{\mathrm{i}}$ – traffic stream, m_{i} – mass of transport unit of movement, V_i – movement speed, T_n – group time, M_d – maximum mass loading.

5. Model of action of transport flows on the bases and platforms with the established aggregate lines of production of high-quality polygraphic multicolor production (Fig. 2).
6. Laser probing method of the spatial structure study object which is the basis for the development of information and measurement systems.

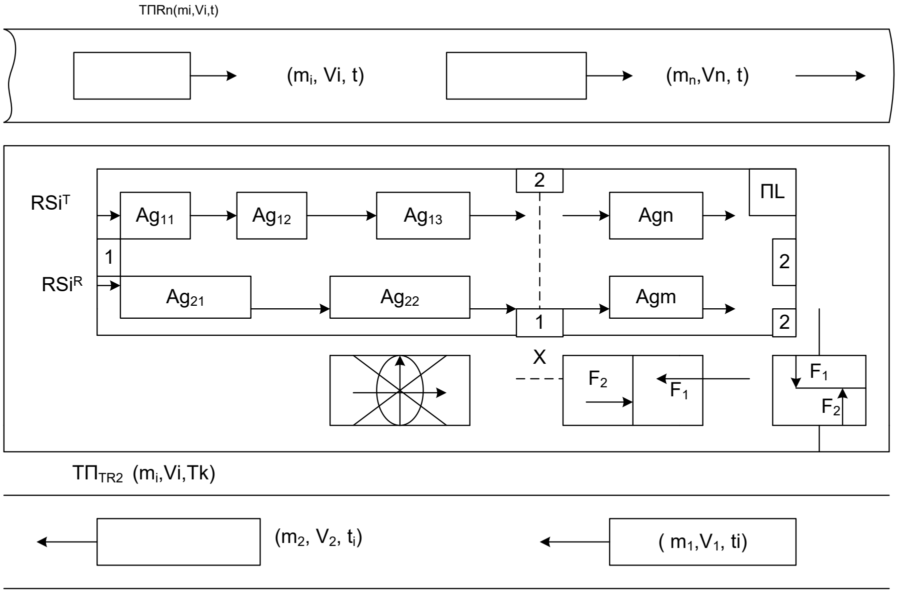

Fig. 2. Model of structural action of factors of influence on the aggregated structure with a common platform: RSi^T – input flow of resources; RSi^R – output flow of resources for the time interval T; $\{Ag_i\}$ – aggregate structure on a common platform $(ПL)$; [1], [2] – coordinates of the installation of the laser system for different sensing options.

Active factors influencing the dynamic and structural stability of spatially distributed objects.

According to the conducted researches, such system active factors of action can be allocated.

Absence of effective control structure and object reliability constructions systems, dynamics of destruction due to deformation shifts under the active factors influence – automobile and transport streams and natural dynamic factors:

1. Conflicts and incomplete knowledge that lead to errors at the stage of designing a spatial structure:

– incomplete data about the object, structures, materials, dynamics, factors, loads, destructive factors, loads, destructive forces;

– gaps in the knowledge system of designers lead to systemic and structural errors.

2. Conflicts that arise during operation in the absence of data and knowledge of staff:

– structure of dynamic loadings and their changes on long and short time intervals;

– seasonal, natural factors, cataclysms that lead to structural damage.

3. Transport flows as stimuli of oscillations of spatial structures of bridges, platforms:

– change in the level of reliability and aging of metal and concrete supports, platforms due to vibrational oscillations;

– dynamic destruction of materials, inadequacy of the project and facility structure to the requirements and trends of traffic and its mass parameters and reliability.

4. Exclusion of active factors on the oscillations of the soils of platforms and supports, deformation from dynamic perturbation and gravitational deformations.

Selection and processing of heterogeneous data on the state and dynamics of spatial objects with vibration.

The modern period of development of science and technology needs to pay more attention to basic research, theoretical generalization of known facts and the discovery of new ones, which become the basis for the formation of the knowledge base. One of the ways to obtain new information in stochastic perturbations is the synthesis of robust algorithms for data processing and creation on their basis of information-measuring systems for vibration control using laser remote sensing of areas of greatest stress and displacement of spatial structures [15].

Depending on the type of construction, the level of vibration (data sampling) is estimated by the method of sounding on the reflected beam (mirror surface on the structure) or direct projection sounding (photomatix installed in the control place of the structure) (Fig. 3).

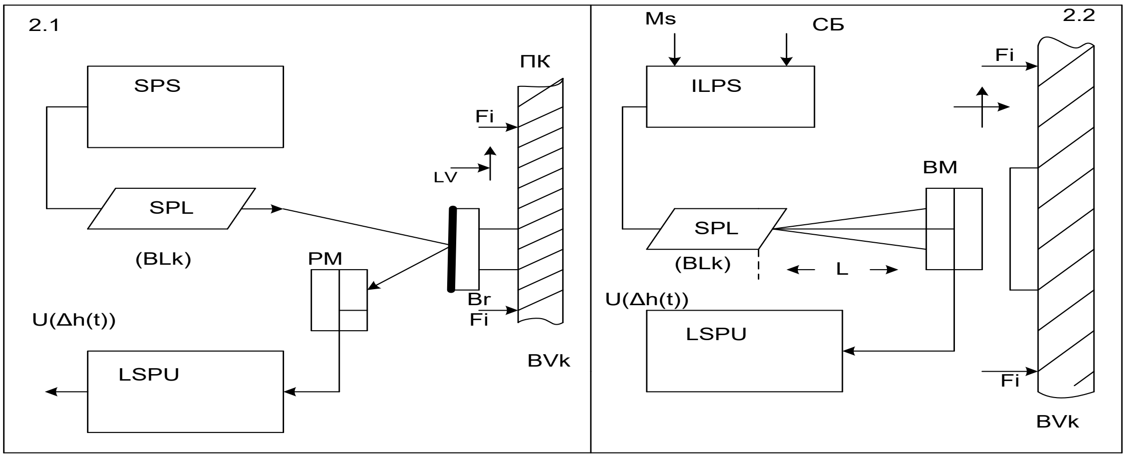

Fig. 3. Schemes of remote sensing of the vibration area of the structure (2.1. – on the reflected beam, 2.2. – projection direct probing)

Symbols in the diagram: NPL – semiconductor projection laser, SPS – stationary power supply, ILPS – integrated laser power supply (network or solar battery), PM – photomatrix with VM basis, LV – laser reflector with Br basis, BOLS – laser signal processing unit, $U(\Delta h(t)$ – vibration signal of the structure. Consider the scheme of vibration transformations of the laser signal when probing a spatial structure (Fig. 4).

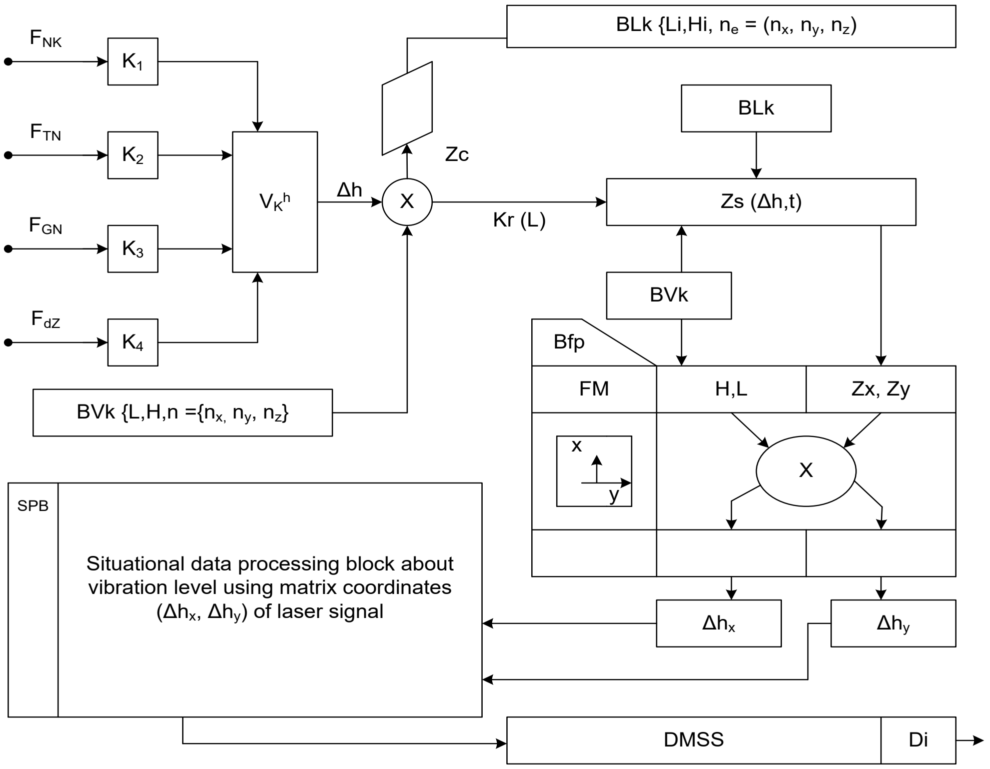

Fig. 4. Block diagram of laser signal transformations at dynamic displacements of the sounding area of the spatial structure: *F_{NK}* – structures dynamic stress factor; *F_{TN}* – dynamic transport stress factor; *F_{GN}* – gravitational stress factor of spatial structure; *F_{dZ}* – factor of dynamic shifts at seasonal changes temperature, humidity, wind pressure; V_K^h – he control displacement area of structural element; *BVk* – geometric domain of control basis; *BLk* – laser installation basis; *Zc* – probing signal; *Zs* – beaten signal; *Kr(L)* – laser beam scattering coefficient

Information transformations of laser signals in the process of measuring the dynamic displacements of structural elements can be represented as:

1. $\left\{\sum_{i=1}^{u} K_i F_i\right\} \xrightarrow{(t,\tau)} \left\{V_k^n\right\} \xrightarrow{Ar(t,\tau)} \Delta h(t,\tau)\big|_{BVk}$ – model of the process of forming the displacement of the structure control area due to the operator of the influence of factors $A_i = (t,\tau)$ at time moment t on interval τ ;

2. $Z_C\left(P,d,F_s(\tau),t\right)\big|_{BLk} \xrightarrow{Az,\Delta} Z_S\left(P_S,d_S,F_S\,|\Delta h,t\right)\big|_{B_{\Phi\Pi}} \rightarrow A(\Delta h \rightarrow \Delta \mathrm{U}) \otimes Z_S(\Delta h) \rightarrow \left(\Delta h_x, \Delta h_y\right)$ – model of conversion of laser signal parameters in the region $\left(V_\kappa^{\mathrm{n}}\right)$ probing the displacement of structural elements under the influence of dynamic factors (P_S – laser signal power, d – beam diameter, F_S – signal form).

$$Z_S\left(\Delta h, P_S, t, F_S(\tau)\right) \xrightarrow{V_\kappa^n} \downarrow \overset{A_{\Phi M}}{\otimes} \longleftarrow K_M\left(\Delta h \rightarrow \Delta \mathrm{U}\right)\big| B_{\phi M}$$

$$\Pi D\left(\Delta h_X, \Delta h_y \,|t, T_K\right) \leftarrow A\lg\left(\Delta U(h) \rightarrow \Delta \hat{h}\right)$$

The model of measuring data obtained in the process of laser probing of the area V_K formed at the output of the photomatrix in the form of a data stream $\Pi D(\ )$ based on the algorithm.

Based on the proposed models of measurement transformations, the information and control system of vibration measurements is synthesized.

Stochastic methods of ICS synthesis mainly use Gaussian models of changing the parameters of the object and the probing signal, with little attention paid to solving the problem of ensuring the robustness of systems and the algorithms stability and processing observation results procedures.

The main studies are conducted in the following areas of statistics and systems theory [1], which are based on [19, 5, 6]:

– probable models of random processes and fields to describe object vibration and influencing factors;

– procedures for detecting, recognizing, estimating parameters and filtering signals based on selected dynamics models that reflect the state of the technical system or spatial object at the current time;

– algorithms of spatio-temporal signal processing taking into account the stochastic structure of propagation channels and perturbation models for estimating real-time trajectories and trends of change of dynamic parameters;

– procedures for multi-criteria optimization of the decision-making process for management in conditions of data inaccuracy, which changes the load mode;

– procedures for dynamic assessment of the situation in energy-intensive facilities;

– algorithms for pattern recognition (spatio-temporal, situational) formed from data streams in different modes of operation of the object;

– procedures for analysis and synthesis of IBC to assess the state of spatial structures of technological objects with varying degrees of control;

– selection of indicators of signs of limit and emergency modes of the current dynamic situation in constructions concerning the target area of admissible parameters.

The classic approach to the structural synthesis of ICS consists of structure development based on the technical task within the existing analysis and synthesis methods, based on a given measuring system model without taking into account the target orientation. However, information on the study object structure, the conditions of its operation with limited resources, observability and reliability are not always fully inasmuch. First of all, when implementing the ICS synthesis procedure, one should keep in mind the goals of the technological object, which allows building a meaningful model and forming quantitative optimization criteria in the form of a system of quality functionalities.

With the stochastic nature of the functioning of the object control, it is often faced a situation of insufficient priori information.This complex problem arises especially when monitoring the state of technological spatial structures, with unidentified structure and functions, unstable in time and blurred priorities, local goals that have no strategic directions, and decision-making procedures that do not have systematic and effective technological support. In these cases, the principle of dual control of the operation process is used for decision-making, which involves the simultaneous use of signals as a means of studying the technological object, the trajectory of behavior under the influence of perturbing factors. But there are conditions under which optimal surveillance and management becomes impossible. This situation occurs when resource constraints or dynamic disturbances significantly exceed the level of informative useful signal. This leads to the disorientation of LIKS and making incorrect decisions, and in extreme conditions to an emergency situation. Under these conditions, the robustness and efficiency of the ICS, built on the classical theory of filtration basis and the automatic systems theory with feedback using the hierarchical structures of Masarovich, are lost. Problems of synthesis of LIX systems, as well as information aspects of ICS functioning as a dynamic situation image shaper in the control channel of the control system, are practically not considered in the literature, which makes the problem of robust systems synthesis. This requires finding fundamentally new approaches to the synthesis of LICS, taking into account the achievements of program-targeted and situational analysis, which allows to adequately reflect the situation in the target space of the DSS system, and analysis of information about based on the interpretation of the behavior of the trajectory of structures under the influence of active dynamic factors in space and time.

Laser sensing of oscillations of the spatial structure of the bridge with a long span

For detection and identifying transport infrastructure spatial fluctuations and large building structures, a projection laser probing changing method to the trajectory of elements at certain crisis points of structures has been developed. According to [6], the spatial displacements of the coordinates of the supporting structures can be represented as trajectories (Fig. 5).

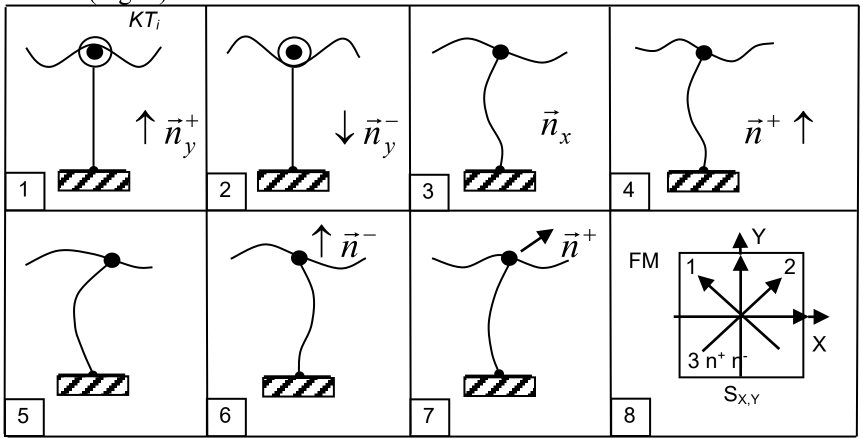

Fig. 5. Spatial orientation of the vectors of active influences on the plane $S_{X,Y}$ on the supports of the bridge with the length of the span from 20 m to 100 and more meters

To receive the spatial flux of laser signals, the photodetector matrix (FM) of the photodetector must have a 4-square structure to estimate the dynamics of the displacements of control points on the vectors $\left(\vec{n}_X, \vec{n}_Y, \vec{n}^+, \vec{n}^-\right)$ according to the difference equation [33]:

$$trak\ \Delta U^t_{\text{var}}\left(\vec{n}_X \Delta x\right) = K_M\left(U^+_{xt} - U^-_{xt}\right) = K_M K_{YS}\left(P^+_{Si} - P^-_{Si}\right)^t,$$

де P^+_{Si}, P^-_{Si} – the power of the received laser beam $\Delta U_{\text{var}}\left(\vec{n}_X \Delta x\right)$; K_M, K_{YS} – the coefficients of transformation of the matrix and scattering of the beam, P^+_{Si}, P^-_{Si} – variation of the voltage at the output of the channel for measuring the oscillations of the control point on the vector $\left(\vec{n}_{Xi}\right)$.

In Fig. 6. the scheme of possible oscillations of the bridge platform and data selection by laser probing of displacement control areas are given.

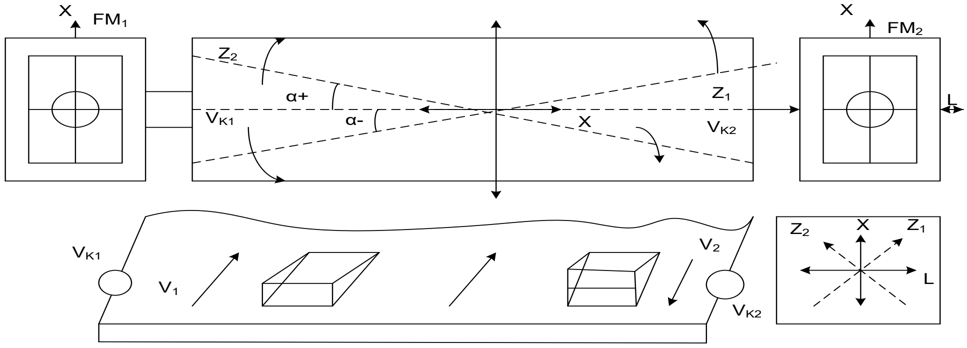

Fig. 6. Oscillations of the bridge deck at oncoming traffic flows with speed $V(t)$ and ground displacements of foundations and platforms

According to Figs. 4, 5 and models of information transformations the structural-information scheme of the method of projection laser sounding of oscillations of the control point of the structure is formed (Fig. 7) [9, 33].

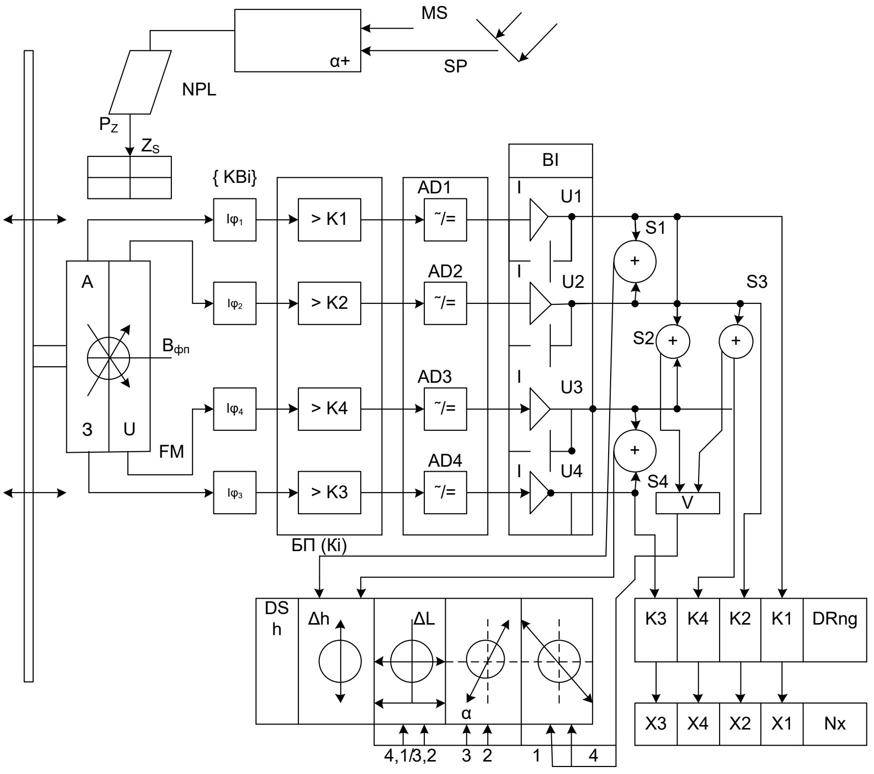

Fig. 7. Laser spatial vibrometer with emission detection (liquid events): *FM* – 4 square matrix photodetector; P_Z – power of the probing laser; P_S – received signal; $\{kB_i\}$ – channels of control of dynamics of oscillations in the base $\{x, y, n\}$ with input filters of signals $\{B_X\Phi_{\text{i}}(f_M, \Delta f)\}$ with frequency f_M and service of transmission Δf; $\{\text{БП}(\text{К}_{\text{i}})\}$ – block of signal amplifiers with coefficient K_i; AD_i – analog signal detectors; $BI(U_S)$ – signal integrators unit; $\{S_i\}$ – operational signal adders; *DRng* – discrete rank load classifier;
N_X – digital indicator; DS_n – display complex indicator of dynamic displacements along axes (X, Y, Z^+, Z^-);
***MS* – mains supply system, *SP* – solar panels.**

Experimental research

Since special permits and equipment are required to study the vibration of bridges, foundations, platforms. Therefore, analogues were used to estimate spatial waves under the influence of perturbations, using high-temperature hydrodynamic flows of viscous fluid $\left(T^0C=[900-1100]\right)$ based on the model of dynamic balance (loading – flow) of resources in different control modes (glass furnace – with lateral selection of molten glass) and laser sounding offset level.

Experiments to assess the perturbation of the glass mass surface by laser sounding were performed on the furnace (Fig. 8) of Rokytne Glass Plant for the period (2010-2011) and other furnaces for the period (1990-2015).

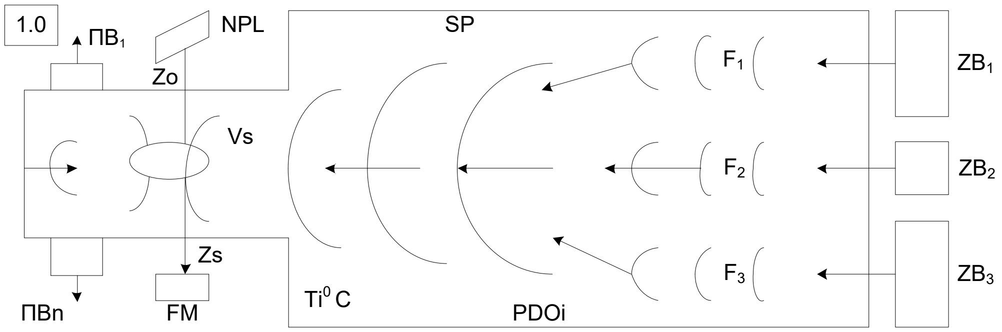

Fig. 8. Hydrodynamic model of surface solitons formationwhere: $\{ZB_1\}$ – loaders (continuous or pulse) charge; $\{ПB_i\}$ – glass mass extraction devices; V_S – laser control area; PDO_i – spatial dynamic perturbations of the volume and surface of molten glass mass caused by perturbation factors $\{F_i\}$.

In fig. 8 shows the scheme of the glass furnace (SP), Soliton effects occur in the control zone when the direct wave of surface perturbation in the mass extraction channel meets the reflected one.

Graphs of the surface displacement trajectory in the sounding field and the dynamic soliton formation mode in the channel of mass selection. The graphs show changes in the object operation modes under different load modes (discrete pushing mechanism). During executing control commands on the loading mechanism inhomogeneous streams of the charge fall on the glass mass surface and excite longitudinal waves. Longitudinal waves propagate along the molten viscous surface, pass along the furnace into the mass extraction channel where under certain conditions solitons of the surface are formed (Fig. 9).

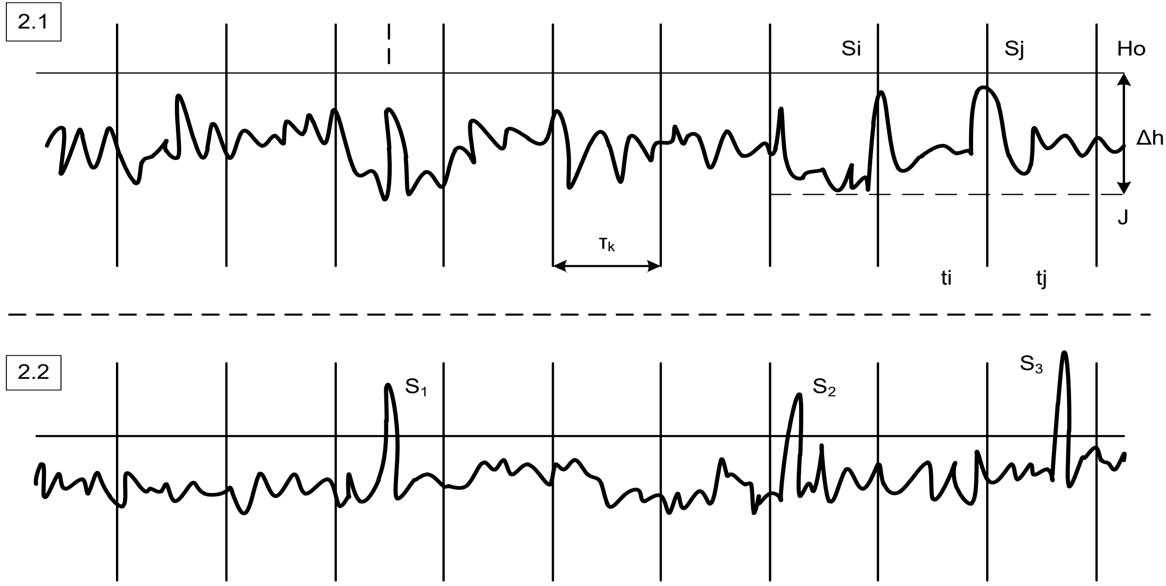

Fig. 9. Hydrodynamic model of surface solitons formation: (top) – the structure of the glass furnace, as a model; where SP – glass furnace in the contour image; $\{3B_1\}$ – charge loaders, as perturbing factors; V_S – speed and loading time $\left(V_{3i},\tau_{3i}\right)$; $\{ПB_i\}$ – flow of product selection; $\{T_i^0C\}$ – surface thermal field $\left(T_i^0C-980^0C\right)$; *NPL* – semiconductor projection laser for surface sensing *FM* – photomatrix of laser signal Z_S reflected from the control area V_S ; $\{F_i\}$ – factors that disturb surface waves at dynamic loading of the resource $F_i=\{m_i,\tau_{i3}\}$ – mass m_i , during the time interval τ_{i3} .

2.1. The graph of the trajectory of oscillations of the viscous mass surface in the probing region V_S, is characterized by the following parameters: $(\tau_K = 60\ сек)$ control time interval, $\Delta\tau_{ij}$ – distance between solitons, Δh_i – emission amplitude, Δ_n – rank of the pulse amplitude scale at $\{N_S = 0.5\ мм,\ A_n = 0{,}005\ мм\}$.

For: 2.1. – soliton amplitude: $S_i = 0.3\ мм,\ S_j = 0.2\ мм$;

2.2. – soliton amplitude $S_1 = 0.2\ мм,\ S_2 = 0.25\ мм,\ S_3 = 0.3\ мм.$

In fig. 10. The scheme of soliton formation is given.

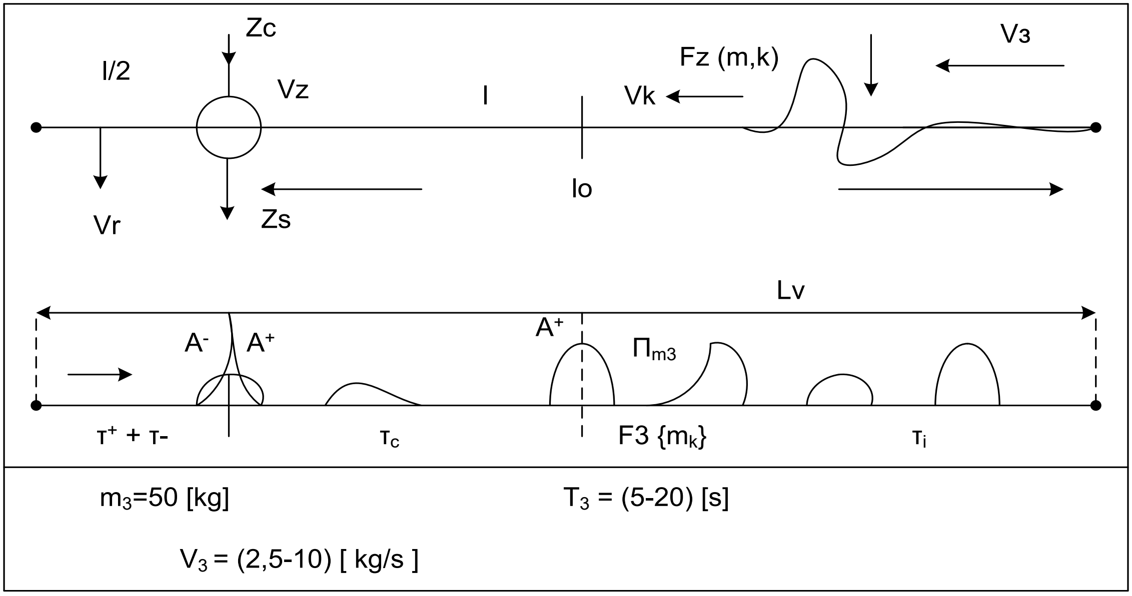

Fig. 10. Model of formation of soliton impulse at loading of a resource on a bath entrance

Designations: V_Z – sounding area, Z_C – sounding signal, Z_S – reflected signal, L_V – bath length, L_O – distance to control area, V_K – loading flow rate, V_r – mass sampling rate at object output, $F_3(m_K)$ – perturbation factor at pulse loading of resource, V_3 – flow rate loading, τ_e – wavelengths at perturbed surfaces: 1. $L_0 = 16\ m$, 2. $L_V = 20\ m$, 3. $U = l = 4\ m$.

Condition of soliton perturbation on the surface in the control area: If at a distance $(l/2)$ to (V_Z) the perturbed surface of the impulse with an amplitude A_1^t at the time t_1, passing to the point l_k at the time t_1 the impulse A_2^+ appeared, then at the meeting at the moment $t_2, (\tau = t_2 - t_1)$ formed a soliton with amplitude $A_{sl} = (A_1^+ + A_2^+)$

For finding the necessary TS control strategy, it is required to conduct a simulation game on the model $\langle CUS \leftrightarrow TS \rangle$ for different classes of perturbations, determine stable Lyapunov regions I_{ZTS} in phase space based on the interval partition, and then the parameters of the strategy for controlling the reliability of spatial structures (Fig. 11).

Typical design errors of ASI, IAS

Expert long-term experience from one of the authors (FMI_AN of Ukraine, Soyuzavtomatika, Center for Strategic Studies – Scientific, Production, Design) indicates that the shortcomings of the project are identified in the first 72 hours after launch of automated production systems of both structural and functional type.

Accordingly, the following mistakes, made by designers can be identified in the development of ACS (automated control system) for both organization and production.

1. Structural errors through the ACS project developing

1.1. The structure of the ACS does not meet the objectives and does not ensure the solution of problems in full.

1.2. The project of the structural organization does not provide for the separation of automatic and operational control and interfaces for its coordination.

1.3. The block diagram of the connection of units does not ensure the safety of energy-intensive units.

2. Mistakes in the orientation of ACS management systems regarding the way to solve a problem situation in a complex system with a hierarchical structure.

2.1. The selected strategies for managing the system mode do not provide a solution to the problem of keeping units within the specified limits.

2.2. The procedures for the transition to the limit area of operation () at maximum loads due to incorrect estimation of the allowable values of the parameter intervals and the intervals of the terminal time of exit from the pre-emergency situation are unclear.

2.3. Incorrectly substantiated logical procedures for the formation of management teams (automatic and operational) to ensure the guaranteed functioning of the ACS and the technological process.

2.4. Professional, cognitive, psychological characteristics and skills and experience of operational staff do not meet the level of requirements for functional management actions.

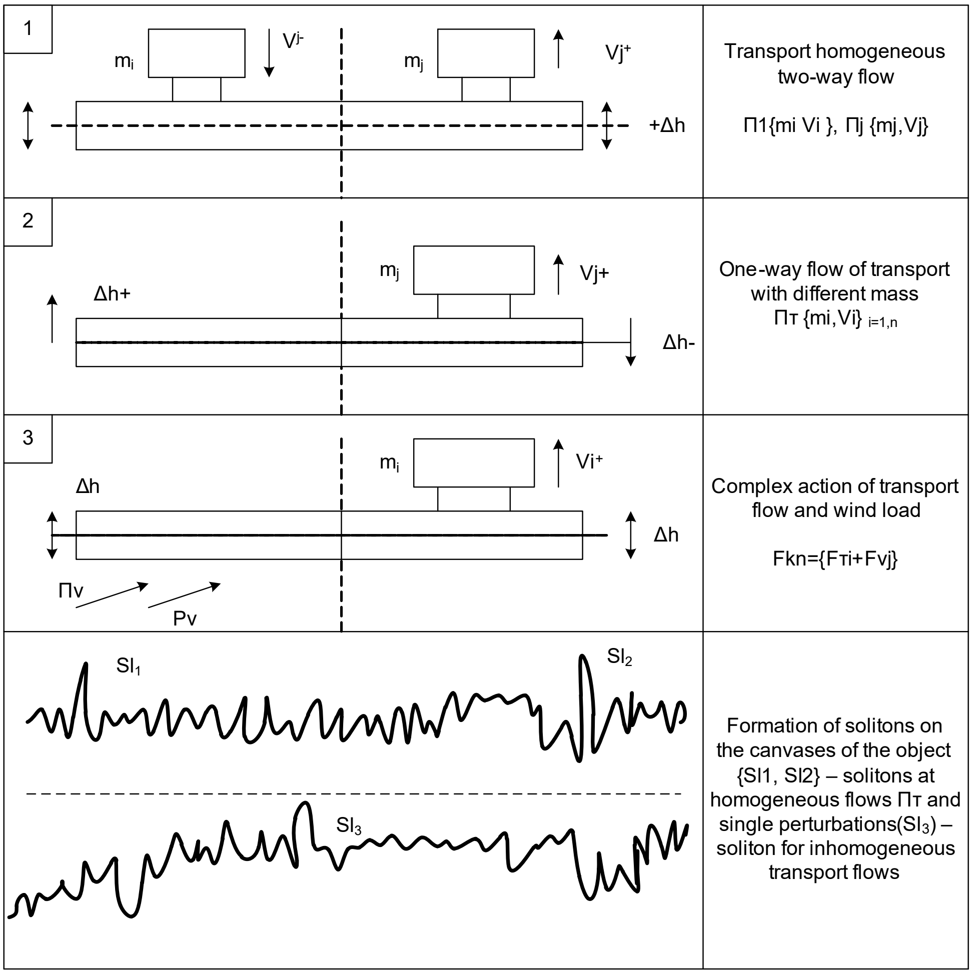

Fig. 11. Models of dynamic loads on the canvas of the bridge

3. Non-coordination of dynamic characteristics of resource flows and dynamic characteristics with the mode of technological process and control actions, as necessary for the sustainable operation of a man-made system or organization.

3.1. Uncoordinated design and regulatory parameters, which is necessary to assess the dynamics of the process of exit from the pre-emergency mode at maximum loads of energy-active units.

3.2. The designers have not fully agreed on the requirements for the dynamics of technological process management, under the influence of obstacles to the control structure and information channels.

3.3. Failure to reconcile the powers of operational personnel to make decisions in extreme man-made situations with the upper levels of the hierarchy of systems.

3.4. Insufficient protection of data collection and transmission channels from information attacks, which leads to disorientation of personnel at the operational and strategic levels to assess the content of the situation.

According to a set of test tables for assessing the level of competence of personnel, candidates for project and operational activities, it is possible to determine the level of cognitive – professional coefficients that determine the projected level of efficiency during project work and operational management.

$Sh(KF_i) \in [0,00-1,0] = I$ and the risk scale.

$Sh\left(\alpha_{risk}\left(KF_i\right)\right) \subset \left[0,00-1,0\right] = I_{\alpha_{risk}}$ build a table of balance of the allowable level of risks of selection of project and operational staff, which provide a guaranteed implementation of the project (Table 1).

Table 1

Balance of acceptable level of risks of selection of design and operational personnel

№	$\sum KF_i$	$\sum \alpha_{risk}$	Type of intellectual, project and management operations
1.	(0,9-1,0)	$\alpha_{risk} < 0,1$	Project work – development of ideas and strategies
2.	(0,8-1,0)	$\alpha_{risk} < 0,15$	Development of the structure and management strategies of the system according to the project objectives
3.	(0,75-1,0)	$\alpha_{risk} < 0,2$	Choice of architecture of control systems and TP units
4.	(0,6-0,8)	$\alpha_{risk} < 0,2$	Document flow, ancillary work
5.	(0,75-1,0)	$\alpha_{risk} < 0,3$	Installation and adjustment works and operational management
6.	(0,5-1,0)	$\alpha_{risk} < 0,4$	Installation work and maintenance
7.	(0,2-0,4)	$\alpha_{risk} > 0,7$	Installation of work inadmissibility

Conclusion

Based on systems analysis and cognitive concepts, crisis situations that arise in man-made systems with energy-intensive factors are considered. It is argued that only if these factors are taken into account at all stages: from design to construction and operation can ensure a high level of trouble-free operation of man-made regional and global structures.

In order to ensure a high level of reliability of man-made systems, it is necessary to take into account in the design process active, informational and cognitive factors influencing the design and implementation of the project, accounting the development of real dynamic situations.

References

1. Sikora L., Lysa N., Martsyshyn R., Miyushkovych Y. Information Technology for Assessing the Situation in Energy-Active Facilities by the Operator of an Automated Control System During Data Sampling. Lecture Notes on Data Engineering and Communications Technologies. 2022. Vol. 77. Pp. 177–187.
2. Marshall V. The main dangers of chemical production. M.: Mir, 1989. 671 p.
3. Dryzdel D. Introduction to the dynamics of fires. M.: Stroyizdat, 1990. 424 p.
4. Haley E. J., Kumamoto H. Reliability engineering and risk assessment (Reliability engineering and risk assessment) M.: Mashinostroenie, 1984. 528 p.
5. Timoshenko S. P. Fluctuations in engineering. M.: Nauka, 1967. 444 p. / Vibration Problems in Engineering, bu Timoschenko. New York - 1955.
6. Dynamics of high-speed transport / ed. Tivilov T. A. - Transport, 1988. 215 p. / Dynamics of High-speed Vehicles, Springer Verlag, V. No. 274.
7. Timochenko S.P. Fluctuations in engineering. M. Science. 1967 - 444s.
8. G. Augusti, A. Baratta, F. Casciata. Probabilistic Methods in Structural Engineering. – London. 1984.- 584p.
9. G. P. Karzov, B. Z. Margolin, and V. A. Shvetsova, Physico-mechanical modeling of fracture processes. St. Petersburg: Politekhnika, 1993. 391 p.
10. Poturaev V.N., Belobrov V.I. Analysis of the dynamics of mechanical systems. K. Vishcha school. 1989 - 151p.
11. Chikriy AA Conflict-controlled processes. K .: Naukova dumka, 1992. 384s.
12. Pavlov VV Conflicts in technical systems. K .: Higher school, 1982. 184p.
13. Pospelov D. A. Situational management: theory and practice. M.: Nauka, 1986. 288 p.
14. Roberts F. S. Discrete Mathematical Models with Applications to Social Biological and Ecological Problems. / Ed. Geiman A. I. M.: Nauka, 1986. 496 p.
15. Perhach OL, Podolchak N. Yu. Corporate conflicts and methods of overcoming them. Lviv: Ed. NU "LP", 2014. 192 p.
16. Kunchenko-Kharchenko VT Information and management documentation in hierarchical systems: Concepts of information security. Lviv: Ukrainian Academy of Printing, 2015. 376 p.
17. Gladun V. P. Decision planning. K.: Nauk. Dumka, 1987. 168 p.
18. Ackoff R., Emery F. On Purposeful Systems. M.: Sov. radio, 1974. 272p.
19. Dragan Ya. P., Sikora L. S., Yavorsky B. I. System analysis will become the basis of the modern theory of stochastic signals: energy concept; mathematical substrate; physical clouding. Lviv: NVF "Ukrainian Technologies", 2014. 240 p.
20. Dragan Ya. P. Energy theory of linear models of stochastic signals. Lviv: TsSD.1997. 361 p.
21. Durnyak B. V., Sikora L. S., Grunik A. I., Timchenko O. V. Laser control of the vibration of aggregates in the transport infrastructure. Lviv: Ukrainian Academy of Health, 2011. 157 p.
22. Hayes D. Causal analysis in statistical studies. M. Finance and statistics, 1981. 255 p.
23. O'Conor D., McDermat I. Systemic thoughts and search for extraordinary creative solutions. K.: Our format, 2018. 240 p.
24. Skurikhin V. I., Kvachev V. G., Valkman Yu. R., Yakovenko L. P. Information technologies in testing complex objects: methods and means. Kiev: Naukova Dumka, 1990. 320 p.
25. Mesarovich M., Mako D., Takahara I. Theory of hierarchical multilevel systems. M.: Mir, 1973. 344 p.
26. Ishimaru A. Propagation and scattering of waves in randomly inhomogeneous media. Moscow: Mir, vol. 1,
27. Filippov A. T. Multimeasure soliton. Science, 1990.- 288s.
28. Duryak B. V., Sikora L. S., Atonik M. S., Tkachuk R. L. Automated human-machine systems for managing the integration of hierarchical organizational and viral structures in the minds of risks and conflicts. Lviv: Ukrainian Academy of Health, 2013. 514 p.
29. Duryak B. V., Sikora L. S., Lisa N. K., Tkachuk R L., Yavorsky B. I. Information and laser technologies for the selection of data flows and their cognitive interpretation in automated control systems. Lviv: Ukrainian Academy of Health, 2017. 644 p.

30. Bychenok N. N., Gaiduk O. V., Mostovoy V. V., Tereshchenko V. S., Senchenko A. D. Predictive-analytical decision support system for regional security. K .: Control systems and machines, No. 4. 2000. - S. 88-95.

31. Vasilenko V. A. Geneza, zmist and ways of implementing the concept of international environmental safety. K.: Bulletin of the National Academy of Sciences of Ukraine, No. 7. 2017. - S. 89-96.

32. Shapar A. G., Mikheev O. V. Conceptual approaches to understanding the processes of anthropogenic destabilization of ecological systems. K.: Bulletin of the National Academy of Sciences of Ukraine, No. 3. 2018. - S. 56-66.

33. Sikora L. S. Laser information and simulation systems for control of TSS technological processes. T2. Lviv: Kamenyar, TsSD "EBTES", 1988. 445 p.

34. Grigoruk V.I., Korotkov P.A., Khizhiyak A.I. Laser physics. - K. MP "Lesya" 1994. - 478s.