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MODERN ASPECTS OF SUSTAINABLE DEVELOPMENT IN CONTEXT OF GLOBAL SAFETY

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СОВРЕМЕННЫЕ АСПЕКТЫ УСТОЙЧИВОГО РАЗВИТИЯ В КОНТЕКСТЕ ГЛОБАЛЬНОЙ БЕЗОПАСНОСТИ

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СУЧАСНІ АСПЕКТИ СТАЛОГО РОЗВИТКУ В КОНТЕКСТІ ГЛОБАЛЬНОЇ БЕЗПЕКИ

Abstract. The authors have considered modern scientific approaches to the problem of sustainable development of complex dynamic systems. Main factors of risks are generalized: anthropogenic, technogeneous and ecological. Some aspects of Darwin's triad and the second law of thermodynamic are used to explain the problems of global safety.

Keywords: sustainable development, complex technical systems, technosphere, noosphere, laws thermodynamics.

Preamble

The fundamental sciences determined the evolution of humanity, especially in the last two centuries. Ideas of such prominent scientists, thinkers, philosophers like Aristotle, Plato, Socrates, Pythagoras, Hegel, Kant, Feuerbach, Galileo, Vinci, Descartes, Newton, Maxwell, Poincare, Lomonosov, Scovoroda, Mendeleev, Vernadsky, Prigozhin and others created the important prerequisites for the knowledge of the spiritual and material world, and influenced the development of creative thought until our time. Of course, many of these ideas will determine the evolution of humanity in the third millennium. Among them the doctrine of V.I. Vernadsky about noosphere (from the Greek "noos" – mind) has to be marked out.

Vernadsky's concept of evolution of Earth's biosphere was published in the first half of the century. He considered the evolution as a single space, geologic, biogenic and anthropogenic processes. In this concept, he outlined the concept of living matter and inert matter, the role of humanity in the development of the biosphere, the global significance of scientific thought as a planetary phenomenon, and the inevitability of the transformation of the biosphere into the noosphere.

According to V.I. Vernadsky new power which "can create the unity of mankind" appeared at the beginning of XX century. Scientific thought was first recognized as a force of geological origin, and creating a noosphere.

Transition of the biosphere into the noosphere is a natural phenomenon; it is deeper and more powerful than the human history. It answers the biological unity and equality of all people and requires a demonstration of humanity as a whole, not only in terms of the individual and the state, but also in the planetary scale. Humanity as a living substance becomes one, some spatial-

ly distributed upper organism having a single information field, existing in a single space-time continuum and managed in common cases, a single biological and social laws.

Very important in the present context is the statement of Vernadsky that the noosphere is the last of many states of the evolution of the biosphere, and the main geological force, the main driving force behind the evolution of mankind, and therefore the main indicator of the noosphere is the growth of scientific knowledge. This process is continuous and irreversible, and in general cases, independent of man.

The correctness of above-stated ideas was confirmed by the whole history of our civilization. Entry into the third millennium of mankind accompanied conditions quite different from all previous history. First of all, accelerated industrial growth of major industrial regions, composed by complex technical systems – such as nuclear and thermal power plants, dams, reservoirs, oil terminals, transnational highway, storage of flammable, chemical and nuclear substances, etc.

On the other hand, the number of natural, environmental and man-made emergencies and disasters are growing that ultimately leads to a sharp deterioration of the environment, and their elimination and subsequent recovery processes drag on for many years and require huge expenses.

All this together has led to the special human existence conditions, the totality of which can be called technosphere, i.e. some habitat of humanity. While mankind is faced with the contradictions between the growing needs and the inability of the environment to meet these needs. This contradiction with increased strength of the economy and a huge number of modern technologies has become destructive for the biosphere and human history of civilization and closer to the moment when the mass of the substance and the amount of energy involved in the technocratic revolution, became comparable to the mass of biological matter of the planet. This has resulted in the modern world on the threshold of ecological disaster.

Thus, a balance that has been achieved in the process of biological evolution over millions of years, violated, and the biosphere is no longer able to compensate for disturbances caused by anthropogenic pressure. Eliminate existing contradictions is possible only within the framework of sustainable socio-economic development that is in harmony with the environment. Quality of human life must be achieved within the limits that do not lead to the destruction of natural biological mechanism of regulation of the environment and ensure its preservation for future generations a normal existence. Ecological paradigm becomes dominant and can significantly change the moral and ethical paradigm of humanity as a whole.

In this context, the relationship between sustainable development and security is very important. Security – is an invariant of the existence of a civilization in the global model of sustainable development. Sustainable development as an anthropocentric and biosphere process is impossible without security (environmental, economic, informational, social, etc.). Even more important is the fact that the transition to sustainable development is only possible on a global scale; any decisions to ensure the security of any object must not contradict international imperative of sustainable development.
Such a systematic and synergetic approach to the problem allows a single unit to integrate the global, regional, county and local aspects of security, but given the planetary imperatives.

System and synergy approach to the solving of the problem makes possible to unite global, regional, territorial and local aspects of safety but taking into account the planetary imperative.

1 Vernadsky's biosphere and noosphere concept in the context of sustainable development

Many scholars in different branches of science were interested in the problem of sustainable development. It is worth to mention the researches of Odum J., Reimers N.F., Legasov V.,

Osipov V.I., D.G. and D.L. Meadows, Moiseyev N.N. and Danilov-Danilyan V.I., Kiselev M.M., Crymskiy S.B., Kaczynski A.B. and many others, to gain some idea of the breadth and importance of this issue. In all these studies was dominated by environmental aspects, often served in a religious and philosophical context. But the problems of science and scientific thought as a product of human activity, the human role in creating an artificial environment – the technosphere, have been paid not sufficient attention. In the view of the authors, the most fundamentally these questions were reflected in the outlook of V.I. Vernadsky [1].

Back in the thirties of the last century V.I. Vernadsky logically clear manner outlined his biosphere and noosphere doctrine and showed that the main force transforming the biosphere and creating new organizational forms of life on Earth is a scientific thought as a function of living matter, the product of human creativity. He noted that the powerful transformative effect on human biosphere began to affect only recently, at the beginning of the XX century, but the course of this effect was produced billions of years of existence of the biosphere.

Vladimir Ivanovich Vernadsky (1863-1945) – a unique phenomenon in the world of science. Born in the XIX century absorbed the ideas and achievements of the first half of the XX century, he was far ahead of his time. All his efforts were directed towards the future.

Let us look briefly on the problems of science and its impact on human. Science plays a dominant role in the creation of modern world history; its multi-vector expression in all spheres of life, and the universality of its existence in many forms – a phenomenon not only positive for humanity. Destructive impulses of scientific advances often cause degradation processes in society.

Initially man existed in a complex, nonlinear, multivariable and stochastic triune world – nature, technosphere and soul. These three worlds existed before, but in recent years have significantly changed accents. A person all further departs from nature, ignores its laws and gradually closing in an artificial world of the technosphere, and world of soul substitutes by artificial virtual world. And in this substitution science also plays a dominant role. The information revolution, the contours of which are not yet completely delineated, especially in terms of its impact on human beings and humanity as a whole, now affects not only positively.

It was the reason of the environmental disaster, the boundaries of which were clearly expressed at the end of the last century. If not touch the discrepancies existing among scientists of different specialties, and inconsistency of terminology, the current state of the relationship between man and nature is as follows.

1. Mankind is on the verge of ecological, or as it is called - man-made disaster, the harbinger of which are: pollution of the biosphere, barbaric exploitation of nature, the loss of biodiversity, uncontrolled population growth, deformation of the social environment, etc.

2. Anthropogenic pressure on the biosphere is increasing at an unprecedented rate: technological capacity doubles every 5-10 years and adequately this growing degree of pollution of the biosphere; more than 7 billion people live on the Earth, and humanity increases about 100 million people a year.

3. Humanity has built technosphere and sees nature as a human construct, as a raw materials appendage to the development of technology, and the needs of technology very often became above human needs; many scientists have expressed the idea of «biological human imperfection» and that at the first stage of a symbiosis of man and machine.

4. The speed of historical events has increased incredibly, amount of knowledge began to double every five years and in the second half of the XX century mankind had receive 90% of all knowledge. However, the scientific problems have been solved fragmentally and there is no enough knowledge for the solution of complex problems of interaction «human-nature». Nei-

ther science nor philosophy have not affected even in the small degree on the self-consciousness of a person: during the last millennium people didn't become better.

5. Over the last millennium in the history of the world there are no significant changes: hunger, disease, war, crime is not eliminated. Science often solves problems generated by it. Word (Logos) devalued and often replaced by jargon; virtual world replaces the real world; human life is devalued; there is a low level of environmental awareness, both in the mass consciousness, and representatives of the political establishment.

6. All this has allowed many scientists to talk seriously about the human catastrophe, they reference to the second law of thermodynamics expressed the inevitability of the destruction of mankind or its part as a result of increasing entropy. Offers recipes to come out of the crisis: environmental education; reducing human pressure on the biosphere to achieve some «ecological balance»; control the development of technology and the transition to non-waste technology; rigid system of legal and economic regulation; strategy formation in the relationship of nature and man (the so-called co-evolution) and the creation of the world of a social order that would be able to implement this strategy, etc.

As can be seen, a single concept of sustainable development is absent. On the basis of such fragmentary ideas is hardly possible to create it in the foreseeable future. It is also noteworthy that many of the proposals in a simplified form repeated ideas of V.I. Vernadsky.

In summary, scientific and empirical generalizations of V.I. Vernadsky are as follows [2].

Biosphere: the basic concepts. V.I. Vernadsky, perhaps for the first time from a strictly scientific point of view consistently and comprehensively summarized and developed the determination of the place and role of man in the biosphere. Concept of «biosphere», i.e. «Area of life» was used in biology in 1804 by the French scientist Jean-Baptiste Lamarck (1744-1829); at the end of XIX century Austrian scientist E. Suess (1831-1914) used it in geology.

V.I. Vernadsky expanded this concept gave him a deeper meaning as «a planetary phenomenon of cosmic character.» To determine the totality of the Earth living organisms, including humans, it is instead the concept of «life» introduced the concept of «living matter», believing that in philosophy, religion and culture, the concept of «life» will always go beyond the «living matter». According to V.I. Vernadsky living substance is the totality of living organisms; concentration of living matter in the biosphere is maximal in some thin layer, called «a film of life.»

It should be emphasized, and this fact is noted in the researches of Vernadsky, the thought about life as a cosmic phenomenon existed before. At the end of the XVII century Dutch scientist Christian Huygens (1629-1695) in his book «Cosmotheoros», published on the initiative of Peter the 1st in Russian in the XVIII century as «The Book of world outlook», advanced scientific generalization that "life is a cosmic phenomenon and it is strictly different from the inert matter". This generalization Vernadsky called «Huygens' principle.»

Biosphere: the living and inert matter. Considering the structure of the biosphere in its physic-chemical and geometrical heterogeneity, Vernadsky noted that the biosphere is composed of living matter and inert substance that throughout geological time sharply divided in its genesis and in its structure. He made generalizations in this sense as follows.

1. Living matter covers the entire biosphere, but by weight it is 0.25%. At the same time, geologically it is the biggest force in the biosphere, develops a huge free energy and detects all processes running in it; living substance has a particular organization and can be considered as a function of the biosphere.

2. Inert matter – solid rocks, gases, sea water, etc. – predominates by weight and by volume.

3. Biosphere has separate dimensions; between living and inert matter is a continuous material, energy and information exchange, which continuously strives for balance.

4. The processes occurring in living and inert matter differ sharply by time and spatially. In living matter they are going on the scale of historical time, in inert matter – on geological time scale. Thousand years of historical time corresponds to approximately 300 million years of geological time. Difference of living matter from inert one also associated with specific properties of the space occupied by living organisms, with its special geometric structure (P. Kury). Louis Pasteur in 1862 noted this phenomenon in the study of inequality left and right phenomena of body. Geometrically rightism and leftism in space can observe only in those cases when the vectors are polar and enantiomorphous.

V. Vernadsky suggested that with this geometric property associated lack of straight lines and the presence of curvature in all existing forms of living organisms, and that the space inside them is not responding to Euclidean space, and corresponds to one of the forms of the Riemann space. He also admitted the idea that space living matter exhibits geometric properties that meet all three forms of geometry – Euclid, Lobachevski and Riemann.

Important principle of Redi goes after the principle of Pasteur-Curie which reflects the regulation of creating of organisms in the biosphere. Incidentally, V.I. Vernadsky made an interesting (especially for mechanics) generalization that the course of scientific thought in creating machines and mechanisms is similar to the process of reproduction of organisms.

5. Summarizing the study of the differences between living and inert substance, V.I. Vernadsky made conclusions, which are very important for our understanding of the sustainable development:

- «all living matter is born of living matter»; should be noted that it is written in 1937, when the opposite opinion of Engels was unchallenged;
- evolutionary process is unique to living matter, in inert substance it is not observed;
- for living organisms gravitational forces are not dominant;
- for inert substance there is no irreversibility, all processes are reversible, while space of living organisms characterized by polar vectors – their direction is not changed;
- difference between living and inert matter primarily manifested by the existence of two major processes: firstly, in the course of geological time the power of living matter is increasing as well as its influence on biosphere and on the inert substance; secondly, there is the evolution of species, i.e. sharp changes in living organisms over time;
- the living space of living matter is other than the space of inert matter; difference between them is so great that the transition from one matter to another in Earth processes never observed;
- area of living organisms' existing is boarded; this implies the existence of a concentration limit of living matter.

Biosphere and man. According to V.I. Vernadsky biosphere is a complex planetary bio-inert natural body that has different heterogeneous structure, i.e. sharp difference of matter and energy in the form of living and inert bodies. Man is an inevitable manifestation of a natural process, which lasts about two billion years. He is a part of living matter, is not self-sufficient, independent of the environment. He is a part of the biosphere, the biosphere's function in the certain of its space-time measurement. A man can think and act only in the biosphere, but the human brain eventually becomes more perfect (D. Dan's encephalosis). This process has never been reversed.

Scientific thought as a manifestation of the living matter. According to V.I. Vernadsky at the beginning of the last century for the first time in human history scientific thought became a real geological force. It was prepared by billions of years of existence of the biosphere and it is a function of living matter. Scientific thought is the force with which a person changes the biosphere; this change occurs independently of human will, spontaneously, as a natural process.

Scientific thought is manifested in the form of universal power – it coverage of the entire biosphere, the whole of humanity – in the creation of a new stage of organization – noosphere. Essentially, scientific thought, as a manifestation of living matter has the properties of orientation and irreversibility.

In the context of these considerations, V. Vernadsky put an interesting question: "Thought is not a form of energy (Lotka). How can it change material processes?" This issue has not been resolved.

Biosphere-noosphere transition. Evolution of the biosphere, according to Vernadsky directly connected with the strengthening of the evolutionary process of living matter. He puts forward as an empirical generalization of the following thesis: «... we should note and bear in mind that the process of evolution of the biosphere-noosphere transition it clearly shows the acceleration of the pace of geological processes. The changes that occur now in the biosphere for (last) few thousand years due to the growth of scientific thought and social activities of mankind in the biosphere were not before.» Mankind is becoming a powerful force capable in its own interests to rebuild the biosphere.

Implications for future research. Considering the biosphere-noosphere outlook of Vernadsky at least three conclusions can be distinguished for understanding the role of human beings, the role of science and scientific knowledge in the general concept of sustainable development:

- humanity is the most important force that defines all the processes occurring in the biosphere; the evolution of the Biosphere identified a person as the most important power to transform the biosphere «in the interests of freely thinking humanity as a whole»; however, the proportion of humanity in the living matter of the Earth cannot increase indefinitely, there is a certain critical limit beyond which self-destruction mechanism may be involved;
- main driving force behind the evolution of mankind, and therefore the main indicator of the biosphere and its more organized form – the noosphere – is the growth of scientific knowledge that, in fact, establishes the primacy of the human mind in shaping world history and the restructuring of the biosphere;
- geological role of human enabled a number of scientists to talk about a new era: L. Agassiz (1807-1873) in 1851 called it the era of human rights; Ch. Schuhert later (1858-1942) called it psychozoic and A.P. Pavlov (1854-1929) – human era. Last name is the most consonant with the concept of sustainable development.

2 Modern concept of sustainable development

To date, it is evident that human intervention in nature nearer to the time when the mass of the substance and the amount of energy involved in the technocratic revolution becomes comparable with the mass of the Earth's biological substance. In this case, the biosphere as a stable structure is actively cooperating with the technosphere – structure unstable and constantly growing. Such interaction in terms of catastrophe theory should lead to a bifurcation, which can occur in two ways.

In the first case tough loss stability of the system can happen, and this will lead to the destruction of both structures.

The second case involves a soft loss of stability, which will be accompanied with local disasters, causing a new structure developing on their own, different from the previous ones, laws.

V. Vernadsky told about alternative chance and special path of development. This path involves the transition of the biosphere into a qualitatively new state – the noosphere, when the brain of all mankind will be transformed into the brain of biosphere – noosphere and some creative leap will be.

From these positions technological progress and its implications for human existence on Earth are considered. In summarizing positions Vernadsky concluded also the main risk factors, among which are the three main ones: anthropogenic, environmental, including natural and man-made.

It should be mentioned that the risk factors are linked in the truest sense and using a fairly complex feedbacks. Their mutual influence can be seen at all levels of research and examination of one of them in isolation from other can be possible only for highly specific cases; in a global sense, the picture will always be distorted. I.e. we can talk about the trinity of human systems "human – habitat – the creation of man's mind" and as an antipode of the system about the trinity of risk factors anthropogenic – environmental and man-made (Fig. 1). We consider them in more details.

One can distinguish at least three major factors: the uncontrolled growth of the population, i.e. catastrophic increase in the proportion of humanity living in the total mass of the Earth; human pressure on the biosphere, leading to reduction of area suitable for the existence of living organisms and human psychophysical features.

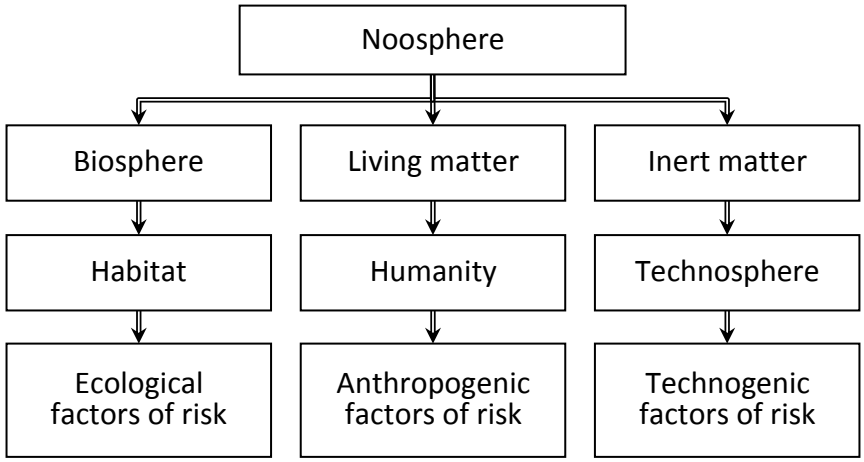

Fig. 1 – Anthropogenic system "Man - habitat - the creation of mind" and the risk factors [3, p. 46]

3 Risk factors

Anthropogenic risk factors. Anthropogenic pressure on the biosphere has become especially noticeable in recent years due to a sharp reduction of areas suitable for human life, reduction of biodiversity, environmental disasters.

Humanity at the present stage of development is more effective than the rest of the animal world in two thousand times (Kovda V.A., 1975): the volume of organic waste of biosphere is 10^7 tons per year, and humanity – $2 \cdot 10^{10}$ tons per year. Production capacity of technological society doubles every 10-15 years and this adequately increases the degree of contamination of the biosphere.

Reported risk factors in conjunction with environmental and natural disasters, decreasing natural habitat, increasing the accumulation of nuclear, chemical and biological weapons, environmental hazards, etc. may lead to the inclusion of self-destruction mechanism of humanity irreversible.

Environmental risk factors. In recent years, human economic activity is so extensive that the normal functioning of the biosphere was practically impossible. For the past 40 years a fifth of the Earth's topsoil has been put out; about an eighth of cropland lost as a result of desertification, waterlogging and salinity; the content of gases in the atmosphere has been increased more

than one-third; area covered by forests in 1950 has been reduced by about a third; ozone layer of the planet has been destroyed more than 5 %.

Excessive concentration of industrial and agricultural enterprises in Ukraine led to catastrophic pollution of land, water and air. Annually more than 17 million tons of harmful substances are thrown into the atmosphere; in most industrial cities, air pollution is in 10-15 times higher than the permissible concentration. From 60.4 million hectares of land in Ukraine one third parts is affected by erosion, humus has been decreased six times; acidic land area increased by 30 %, saline – by 25 %. In the Carpathians, forest area declined by more than half, and in the mountainous areas they occupy 53.5 %, and in the plains – less than 2 % of total area. Over the past 30 years for the construction of technical facilities were used more than 2 million hectares of arable land.

There are about 10 million species in the world and the natural rate of their extinction is 4 species per year. According to scientists in the coming decades about 50 thousand species will disappear per year. In this case the loss of species is absolutely irreversible and disastrous consequences of this process may affect the very near future.

In the field of mining and metallurgical and chemical industries human activities become commensurate with the activities of geological processes on Earth. Due to emissions of carbon dioxide and other gases greenhouse effect occurs: annual average temperature of the planet increases by 0,02 °C, which can lead to the melting of ice and flooding of the continents of the Earth.

Due to environmental risk factors the humanity has been faced with the alternative of further development in the direction of the technosphere, which was selected in the last century. The greatest successes in the field of technosphere – space-rocket and nuclear technology, transport systems, chemical production, complex technical systems, urbanization accompanied by the monstrous man-made emergencies and disasters, and ultimately lead to a decrease habitat. This process is exacerbated by the growing number of natural disasters: earthquakes, mudslides, floods, typhoons, volcanic activity.

Man-made hazards. The most urgent problem of our time is the safety of people and the environment, business processes and technology, machinery, equipment, complex technical systems. The largest technological accidents and disasters that have occurred in the last decade, have claimed thousands of lives, caused a large and often irreparable damage to the environment. Direct costs of responding to them reach billions of dollars.

These disasters by the strength of their influence go beyond national and become a global concern. Despite the significant difference in the economic and cultural development the most countries are experiencing the same vulnerability to the threat of accidents and disasters.

Particularly vulnerable to accidents and disasters are the major cities and industrial regions. In this regard, Ukraine has a special status, as its territory rich in complex engineering structures: nuclear power plants, oil and gas pipelines, transportation systems, dams, reservoirs, etc. In this case, multistage, or so-called synergistic disaster are very dangerous. So natural disasters generate technological accidents and technical accident exacerbated natural disasters.

The concept of protection of humanity, the environment and technosphere objects from natural and man-made emergencies and disasters. World history of mankind has approached the so-called anthropogenic era, i.e. for such a period, when the determining force is the growth of scientific knowledge. Stochasticity of the process, the powerful influence of the moral and ethical rules, irreversible changes in the habitat, the uncontrolled growth of the technosphere, all the negative impact of the transition of the biosphere into the noosphere difficult to adequately predict the further evolution of humanity. In this rapidly changing, unpredictable world

the multi parameter attempt to create a unified concept of global human security is a very complex and problematic.

Some generalizations are published in the known literature [4]. Many countries have developed their concept of transition to sustainable development, taking into account their specific global problems. In Ukraine, the concept of transition to sustainable development was developed by the National Academy of Sciences of Ukraine and published in 2007. The concept is made as a system to balance environmental, economic, social and human dimensions of sustainable development in Ukraine.

4 Sustainable development in the context of science

It should be recognized that modern science based on the use of classical methods of mathematics, physics, mechanics, biology, where is based on the laws of interaction of material bodies, chemical transformations of substances and energy transformations, is not able to solve global problems such as managing or interacting with Nature. World of Newton-Laplace, and it is there we live, almost exhausted. Modern science – synergetic, catastrophe theory, cybernetics, self-organization theory, theory of no equilibrium structures and others – are in their infancy. Thus science, rather its thermodynamic branch is powerless against environmental catastrophe.

Traditional mechanistic approaches with their simplified phenomenological models and complex, and therefore in most cases ineffective mathematical apparatus, have been unable to resolve problems in describing the behavior of living matter. Philosophy of Pascal, Rousseau, Descartes, Feuerbach, Hegel, Kant, as well as Berdyaev, Solovyov, Florensky and others, is not able to meet the challenges of these complexity problems. V. Vernadsky noted: «... I, as a philosophical skeptic, I can safely discard without harm and with benefit of the case of my scientific work all philosophical systems that are still alive.»

This paradoxical situation is not accidental; neither science nor philosophy considers the human from the multi-vector point of view. However, a person in the somatic sense is part of the biosphere and beyond it cannot exist. Therefore, all of his actions should be, and there will inevitably be consistent with the laws of nature. Otherwise, unknown to mankind mechanisms will be switch on as a feedback law, which will regulate the number of people on the planet. However, the human mind, to create a science that transforms the world must find a way out of this situation. Although the «world's Ark» is overloaded, scientific thought cannot lead to results contrary to the process which it was created (V. Vernadsky).

Science and psychophysical features of the person. Throughout its history, mankind has sought to move away from the chaos and at the beginning of the third millennium approached him again, this time too close.

As for the mental and physical characteristics of a person, then, from Socrates to Montaigne, Pascal, Jean-Jacques Rousseau and later philosophers, this issue was discussed carefully with concepts such as uncertainty, contradiction, confusion, deviation from the rules. People seemed not only as a reasonable man (Homo sapiens), but as a person crazy (Homo demens). He imagined himself as a king of nature, but he is not ready for it. His work is related to the introduction into the world of disorder. If the order of nature is associated with a predominance of homeostasis, regulation, and pre-programmed, the human order is a fair amount of confusion. According to Edgar Morin, there is less clutter in nature than in human life; human truth makes a mistake, the human order admits mess.

That is why in the third millennium, we must note that our knowledge about the unity of the «man – nature» is very limited. However, we must agree with the known fact that if the principles of natural selection could be fully extended to mankind, then its existence would have ceased many centuries ago. Nature would not tolerate such being with so contradictory traits, so

little adapted to the environment, taking so much from the Nature and returning back so little. Humanity is a single species that does not live in harmony with nature and makes a mess of her life significantly. If you approach this issue from the standpoint of classical thermodynamics and consider humanity as an open subsystem of a total system of nature, we must admit that at the dawn of self-organization of mankind, its harmonious relationship with nature were significantly higher. So-called civilization has made a mess in this relationship and put the community of people on the brink of total chaos, brought to a line of self-destruction.

However, the logic of life, the amazing survival of humanity and its undoubted supremacy on the planet are forced to take on another human paradigm.

Apparently, it should still be recognized the vague idea that man is a unique creation of nature, part of a universe. His nature is dual and like a wheel – one part of it touches the ground, and the rest of it is in the space (the Optina Elder Ambrose).

Consequence of this process is to change the qualitative characteristics of humanity. The law of natural selection is no longer decisive, humanity ceases to be a collection of individuals and becomes one, some spatially distributed upper organisms whose development is determined not only by biological laws, but also by social laws, developed in the course of a long evolution and constantly changing depending on the external conditions.

According to scientists, this way of mankind development has unique features: advanced forms of self-organization, the lowest level of entropy, perfect forms of creation and processing of energy and information, the most dynamic development. Ancients were right: The man – a whole universe, all that has been and can be.

Human activity in recent years has led to so global changes in the environment that many scientists see in them signs of apocalyptic. This is reflected in a peculiar interpretation of the basic law of thermodynamics. According to the second law – entropy of the world tends to a maximum, and its growth will inevitably lead to chaos in any system. If this law is fully applicable to biological systems and prerequisites for this is more than enough, we can speak about the prospect of mankind tragedy of life. Nietzsche expressed it quite prosaic: «In all its ways humanity reaches a deadlock».

Recent years the idea that the second law of thermodynamics is not entirely applicable to living organisms has been developed. The self-organization of living matter opposes to the growth of entropy. Using the Vernadsky's concept, we can assume that there are reasonable forces in our world which support the whole mankind organization. Otherwise, the increase of entropy, i.e. increase of disorder in society, would lead to the general chaos.

In this context, and apocalyptic is not perceived as the inevitable end, but as the idea of a renewed world, a breakthrough to the existence of humanity in a new way. Humanity has created problems itself; and there are optimistic premises that mankind will solve these problems.

Synthetic world: brilliance and poverty. With some degree of conditionality, we can assume that the history of the world had three scientific and technical revolution: Neolithic, associated with the transformation of substances; Industrial Revolution (18^{th}-19^{th} centuries) – the main indicator of it was the transformation of energy; and the information revolution, which was initiated in the second half of the 20th century in connection with the development of cybernetics, and the rapid spread of the computers. All these revolutions significantly changed civilization. The most radical of these is the latest revolution, characterized by a breakthrough in mega- and macrocosm, space exploration, the development of genetics and bioengineering, the creation of artificial intelligence, etc. World history has been mainly determined by the advances in science; amount of knowledge has become double every five years; only during a half a century, humanity has received 90% of all knowledge.

However, this acceleration of world history could not pass, and not passed to mankind without a trace, without negative consequences. The dialectic phenomenon began to operate, according to which any process causes «retroactive forces» (Hegel), which alter the vector process. The increased speed of historical events led to the rupture between past and future; «The time is out of joint» (Shakespeare).

If we compare the moral principles of antique human and the modern one the comparison is not in favor of the modern man. The values have been changed, and «change of values – it builds change; always will be the destroyer who becomes the creator» (Nietzsche).

All components of modern life – the environmental crisis and the prohibitive sprawling synthetic world, displacing Nature, and the virtual world, displacing the real world – no longer just an abstract idea; mankind for the first time faces the problem of survival and science should say its weighty word. Science is the ordering and some guiding principle, that science should explore new conditions of complex relationships of the biosphere and man. According to P. Moiseev one of the most important challenges facing science is to specify the acceptable criteria and develop those human behaviors that would allow him to find his place in this complex, contradictory, multiparameter world, to find its place in the biosphere.

Ecological imperative in the XXI century. As already noted the basic thesis of this paper is the fellow: humanity is on the verge of a global environmental disaster, and if not taken positive steps, the ecological imperative can cancel imperative political and moral-ethical.

The authors share the view of many scholars that in the third millennium issue of sustainable development is one of the fundamental for all mankind. However, it should be stressed, it is not a new problem and its origins go back thousands of years. In IV century BC Epicurus warned his fellow citizens: «Do not rape nature but obey it.» But even then there were other opinions: Heraclitus suggested not listening to nature, and dissecting it in the process of experimentation, and conceptually. Later this view supported Bacon, Herzen, and Michurin, Heidegger and many others.

Ecological imperative builds awareness of society not as a conglomerate of mechanical, biological and social components but as a holistic education, nature, habitat - not just our environment but we ourselves. Without an understanding of this seemingly banal truth, it is impossible to understand the strategic direction of the development of civilization, i.e. reorientation of the strategy of «growth boundaries» on the strategy of «organic growth».

5 Problems of sustainable development of eco-technopolises

The discussed problem emerged at the end of the last century and, therefore, literature on the sustainability of such complex systems is virtually nonexistent. There are quite extensive publications on reliability and safety, but they do not affect the environment, human rights and sustainable development in whole. However, this problem for Ukraine is very relevant, because in the major industrial regions such as Pridneprovsky, Kharkiv, Donetsk there are a significant part of technological infrastructure and high-quality agricultural land, as well as substantial portion of accidents and disasters.

Self-organization of ekotechnopolises as complex systems. Ekotechnopolis is a complex system that includes technosphere (plants, industrial enterprises, transnational and national oil and gas pipelines, energy, etc.), the ecosphere (land, water bodies, etc.) and cities with their complex infrastructure and transport communications.

Ekotechnopolis (ETP) is not only a quantitative parameter; it is a qualitatively new phenomenon, which has a number of unique features that attract people. Among them:

- the greatest opportunity for the establishment of production, business and social contacts and communication; economic and social benefits for the creative industries; reducing pro-

duction costs through specialization and concentration of production; development of high-tech industries;

- concentration of banking capital, finance, consulting and other services, and all the consequent advantages for business development;
- complex territorial structure; individual regions of an ekotechnopolis may vary greatly in the level of concentration of population, production, capital, quality of life, etc.

Overall ekotechnopolis can be represented as a complex system, as a collection of a large number of elements which interact with one another and the environment to achieve specific goals, forming this inseparable integrity.

An important feature of the ETP is to transfer their information and availability of management processes. ETP have unity of purpose, i.e. their behavior is subject to the achievement of certain goals (for some companies, for example, it may be a profit), and the property of self-organization, i.e. they are in the process of functioning can alter its structure. For ETP is typical to have different levels, often not concordant goals. ETP are dynamic systems, they are able to change its state over time. ETP – non-deterministic (stochastic) system, since the knowledge about variable values of systems at a certain time does not allow establishing the state of the system at any subsequent time. From a thermodynamic point of view ETP is an open system, constantly exchanging energy, matter and information with the environment. According to the second law of thermodynamics for open systems the steady state is moving equilibrium in which all macroscopic characteristics remain unchanged, but extend continuously macroscopic processes of energy, matter and information input and output.

Thus, ETP is a psycho-informational versatile, multi-functional system; a self-organizing system, with negative and positive feedbacks, principles of homeostasis and metabolism are inherent for it; it has stochasticity and unpredictability. The main source of unpredictable dynamics of development is the self-organization processes emanating from the nonlinearity of all functional dependencies, feedbacks and the phenomenon of bifurcation mechanisms. If add to this system a person with its inadequate and unpredictable behavior, the ability to take risks, the presence of emotions and special psychological and physical qualities, the picture is even more confusing. Therefore, we consider all the components of the difficult process of self-organization separately, paying more attention to those that are needed for further research.

One of the features of ekotechnopolises as complex systems is the presence of structure elements that have often one purpose, but significantly different not only in their functional purpose, but also in relation to the problem of sustainable development. First of all, we mean industry and agricultural enterprises. First due to the specifics are in constant conflict with nature, their activity is detrimental, sometimes irreparable for the environment; second, usually exist in relative harmony with nature and the damage caused by their activities disproportionately smaller. Consider these two elements common system in more detail.

Agricultural enterprise is a complex psycho-informational, multipurpose and multifunctional system, controlled by man. It is dynamic, cyclical by the nature. In contrast, for example, from steel mills, a program of agrarian enterprise is strict and predetermined: the plant has no time factor (any items can be made at any time and in any order); in the agricultural enterprise it is impossible to gather the harvest before the whole cycle will not pass field work. I.e. in the space-time continuum, which can be represented by an agricultural enterprise, you cannot change the order or carry out permutation operations, both in space and in time.

The system of the agricultural enterprise is controlled by man, but man as a link of management, all his actions agrees with the actions of nature: nature gives all the basic laws of development of the system, their kinetics, and cyclical timing. The system has all the features of

self-organization: the unpredictability (rain, hail, heavy rains, frost, and natural disasters); non-linearity of all functional dependencies, the system is always bifurcational.

As you can see, the process of managing of such systems is very complex and requires of certain assumptions.

ETP as any psychophysical system in its development process goes through four phases:

1) generation and formulation of the idea of creation;

2) creation of a test prototype of ETP;

3) test the viability of the prototype;

4) improvement of ETP with bringing to the optimum level.

Principles and laws occupy the important place in the evolutionary process and development of the ETP. They can be generalized as follows:

1. All processes in the ETP are non-deterministic; by their nature, they are stochastic and uncertainty.

2. All ETP exist in a space-time continuum: their present and the future are determined by the past.

3. All development processes of ETP subject to certain laws, playing the role of selection principles; this are Darwinian triad, and Newton's laws, and mechanisms of development, and the law of divergence, and synergistic or cooperative arrangements, etc.

Darwinian triad. Today the idea about the trinity of the material world has spread. Inanimate nature (inert substance) and living matter are the links of one chain with a single development process. If it is so, it is logical to try to describe this process in one language, with one voice, reflecting the genetic relationship between the individual hierarchies, use a single scheme and a common terminology for all fragments. N. Moiseev proposed to use Darwinian triad as the basis for investigation of the general properties of inanimate matter, living matter and non-governmental organizations: variability, heredity, selection.

Variability in this case is stochasticity and uncertainty as a basis of functioning of all the mechanisms of our material world. «The world is unstable» – these words of Prigogine express the essence of any system, regardless of its level of organization.

Under the inheritance we mean the ability of matter to maintain their characteristics, as well as the ability to change from past to future. I.e. in Darwinian triad heredity is a term that reflects the influence of the past on the future.

Selection in biology is interpreted as the principle of «survival of the fittest.» Similarly, in the inanimate nature principles of selection are all conservation laws, the laws of physics and chemistry, in particular the second law of thermodynamics; economic principle of selection is a balance condition, etc. In the XVIII century, it was found that the actual movement of the plurality of virtual selected using Newton's laws, which are in this case the simplest principles of selection. Among them are the variation principles of «economy entropy»: the principle of minimum potential scattering (L. Onsager), principle of minimum entropy (Prigogine) and principle, or rather an empirical generalization, the minimum energy dissipation of (Moiseev).

Basic thermodynamic principles. In the XIX century there were two important and contradictory ideas, which have, nevertheless, a significant impact on all of our research time. Introduced by Darwin the idea of evolution in biology (adequately and in sociology) is associated with an irreversible increase in the organization, with the creation of more complex structures. In thermodynamics and statistical mechanics, the idea of evolution is formulated as a principle of Carnot-Clausius. In its modern form the content of the second law of thermodynamics as follows: for open systems exchanging energy and matter with the environment, the change in entropy dS during the time dt can be decomposed into components

$$dS = d_eS + d_iS, \quad (1)$$

where d_eS – entropy flux from the environment;

d_iS – entropy production due to irreversible processes within the system.

The second law thus states that for all physical processes

$$d_iS \geq 0, \quad (2)$$

where equality applies only to the case of equilibrium systems.

In the approximation of an isolated system (energy E is constant) $d_eS = 0$ and (2) takes the form

$$(dS)_i \geq 0$$

i.e. entropy of an isolated system increases irreversibly and, therefore, the evolution of such systems is always directed to a continuous disruption, i.e. to chaos, to the destruction of structures. Consequences of this law are quite unexpected: if a structure was appeared in a certain period of time, in the future its order will be annihilated in a progressive chaos corresponding to the most probable state.

The idea of biological evolution has completely the opposite direction. Combination of these two opposite aspects of evolution is a topic for different scientific schools. Consideration of the various aspects of this important problem is beyond of our research.

According to Prigogin [5] order of the system is carried out through fluctuations, and the emergence of the new structure is always associated with the result of instability, i.e. with the advent of the significantly stochastic element.

In 1947 Prigogin formulated the theorem of minimum of entropy production, which «... claims that the system which is in steady state, sufficiently close to an equilibrium state, produce the minimum of entropy». This theorem is a very universal principle, which allows managing the self-organization of complex dissipative systems. It also gives criteria of evolution, which means that the system will necessarily evolve to no equilibrium steady states. Evolution thus contains a certain thermodynamic principle that in the nonlinear region can be expressed in analytical form

$$\int \frac{d\sigma}{dt} V \leq 0,$$

where σ – module of entropy in some volume V.

To further processes decompose $d\sigma$

$$d\sigma = d_x\sigma + d_j\sigma,$$

where j – flows or speeds associated with irreversible processes;

x – generalized forces leading to these flows.

For dissipative systems which are in a state of stable equilibrium, evolution criterion can be written as

$$\int d_x\sigma dV \leq 0.$$

Here we make very important conclusions for further research. For open systems, including systems and psycho-information nature, due to the influx of external matter, energy or information, there are more or less stable condition, so-called «quasi-equilibrium structures» in which the entropy is not only increases, but is locally reduced. From the standpoint of classical thermodynamics, these structures are not in equilibrium – a balance here is understood only in the sense of stationarity. Decrease in entropy is associated with the presence in the system element «living matter», i.e. man. Left to itself, any complex technical system, regardless of the form of perfection, according to the second law of thermodynamic, and due to an increase in entropy will be completely destroyed. And only human presence allows the system to be self-organized and transformed into more complex structures.

The second conclusion is as follows. If in an open system there are several types of organization structure, a structure that meets the maximum decrease in entropy will be implemented.

And as a decrease in entropy is only possible due to the absorption from the outside of matter, energy or information, so only that structure which is capable to absorb maximum can be realized. It should be emphasized that for systems with complex hierarchy, this principle can be extended to a subsystem, which can locally decrease entropy.

Organization and feedbacks. The term «organization» means a set of conservative, slowly changing system characteristics. Using this term, we can represent the process of self-organization as a change in its organizational forms and describe the processes of development of the system in a sequence of transitions from one quasi-stable states characterized by certain parameters of the organization to others.

Processes of evolution, as well as synergistic model can be described in terms of states. This can be phase variables or functions, sometimes functional depending on the phase variables. In the transition to the description of living systems or psychophysical complex technical systems such as enterprise organization concept is somewhat complicated and should include not only the conservative characteristics, but also all those features of social, economic and emotional nature that determine the livelihoods and status in a time-space continuum. Such systems characterized by a completely new type of development mechanisms, having a common name – feedbacks. This mechanism is unique only for systems of wildlife not for inanimate matter. Now consider two terms homeostasis or homeostasis (like state) and metabolism that are essential for the evolution of systems.

Homeostasis means that any living being or any living system is peculiar desire for stability or for self-preservation. Such systems under the influence of disturbances from the external environment within certain limits can change their state. Underlying mechanisms of such changes are negative feedbacks that maintain homeostasis.

In 1948 W.R. Ashby applied the idea of homeostasis to support a wide range of simulation systems: biological, technological and social. He showed that during the evolution of open systems usually increases their stability, produced more complex and multi-level complex feedbacks. However, the absolute homeostasis unattainable – in a living organism that prevents aging, in technical systems – the destruction, deterioration, accident; in the social environment, conflict, revolution, etc.

Aspiration systems to homeostasis promote stability, at least for a certain period of time.

However, the dialectics of development suggests that too stable systems terminate their evolution; for them the resistance hampers the implementation of the principle of variability. Excessive adaptation (or specialization) does not contribute to improving the system.

Metabolism is the property of open systems to the exchange of matter, energy and information with the environment. This property is common to all systems of this type, which are due to external energy, matter and information change their local entropy.

By **feedback** we usually understand such type of interactions when there is some freedom of choice and that choice is made for a specific purpose. It should be emphasized that in inanimate nature feedbacks do not exist, they are unique to living beings. This conclusion is open to discussion but for our further research it is important to define that managed process, by definition, involves the participation of living matter. An example is the ETP where technical devices and technologies are controlled by man. In this case, the control makes sense only when there is a definite purpose, such as business profits or production volume. This goal creates a certain type of management, which in turn creates a new selection mechanism. Formally, this is as follows. Let purpose described by the following terms and conditions:

$$f(u,x) \Rightarrow \max, \quad u = u(x,t),$$

where*x* – vector defining the state of the object;

u – free parameters of control;

t – time.

The system to be sustainable must be observed conditions

$$f(u) \Rightarrow \max,$$

where $f(u) = \begin{cases} 0, \text{ if system is sustainable,} \\ 1, \text{ if system is not sustainable.} \end{cases}$

Thus, the condition *f (u, x)* => max determine the control action of *u* as a function of state *u* = *u*(*x*). This will be the mechanism of selection or feedback derived from the existence of a particular purpose.

Thus, for technical systems involving human important keywords are: purpose, decision making, feedback, and information entropy. All these concepts are dialectically interrelated by the complex functional linkages.

Processes of development of complex systems. Consider first the inanimate nature. The motion of any system can always be described in terms of multicriteria optimization problem

$$\varpi_1 \Rightarrow \min; \varpi_2 \Rightarrow \min; \varpi_3 \Rightarrow \min\ldots \quad (4)$$

whereϖ_1 is functional, minimization of which ensures the conservation laws;

ϖ_2 – functional, minimization to carry out the kinematic conditions, etc.

It is well known from the mathematical analysis that to minimize some functional we need to perform several conditions. Let F be a set of extreme values of the functional ϖ_1. Then the problem $\varpi_2 \Rightarrow \min$ would make sense if we, for example, to search for the minimum value of the function ϖ_2 on the set F_1 etc. Thus, the set of functional must be ordered and enumeration sets F_i, the minimum values of functions ϖi is not empty. That requirement (4) defines a set of admissible states of ϖ. That this set is the arena of developing events.

Stochastic approach is widely used in other areas, in particular to determine the reliability and safety. Despite its versatility and well-developed mathematical apparatus, it allows the repetition of events, such as accidents and he doesn't take into account unique events such as disasters. Structural theory allows to avoid such methodological flaws combining deterministic and stochastic methods [6].

In systems with elements comprising human the picture is much more complicated due to the principle of self-preservation or homeostasis. In this case, the motion of the system can be formalized as a set of conditions, each of which admits a variation form

$$\Phi_i(x) \Rightarrow \min, \quad i = 1, 2, 3\ldots$$

However, with respect to the functional F_i, nature does not entitle them to automatic ranking, as all determined by the principle of natural selection. Last defines a functional π for which a minimum behavior x_1 exists and $\min\pi(x) \Rightarrow \pi(x_1)$. But a person cannot observe the behavior of x_1 to any external circumstances. However, the closer it is to the behavior of x_1, the more chances he has to adapt to the particular condition. If you change the parameters of the system, for example, emergency ETP, each person has his own «optimal» way of behavior, and therefore different ranking functional F_i. I.e. convolution formation became the prerogative of the individual intelligent behavior: measure of professionalism, the will to achieve the objective, measures of responsibility, etc. In this case, the action takes one of the most important principles of selection: the maximum local entropy decreasing due to metabolism, i.e. by the use of external energy, material and information.

Self-organization of such systems, i.e. systems involving human subjects, comes amid irreconcilable contradictions: on the one hand, the system seeks to preserve homeostasis, i.e.

stability. On the other hand, it seeks to maximize the absorption and the use of external energy, materials and information. In principle, the development of such systems can be summarized in the language of multiobjective optimization compromises for different conditions of existence.

In control systems man plays dominant role: he introduces a degree of uncertainty, and its subjective view of how to ensure sustainable development changes the selection algorithms. The principle of variability, for example, is largely determined by the objectives and functions of the ways to achieve it.

In wildlife adaptation mechanisms predominate and bifurcations occur only in exceptional cases. Leibniz was right: "Natura non facit Saltas", i.e. «Nature does not make leaps». In psycho-information systems it is very difficult to predict human action, because to change the same parameter of the system two people can take completely different solutions. I.e. each state of these systems is a bifurcation. This leads, on the one hand, to developing ways of uncertainty at each time point and on the other hand, to acceleration of the development of self-organization of the same system. For such systems, the most important is the act of making decisions, which ultimately determines the feedback.

As can be seen from the above arguments, for the development the system need not only negative but also positive feedbacks. System using only negative feedback tends to stagnation, to the degradation of organizational forms; at a certain period of time, such a system can be sustained and maintain constant parameters, but it cannot evolve.

A good example of this is the changes in the modern life of large enterprises. Those that have not changed in the 90th for some time had certain stability: their internal structure remained stable, energy, matter and information is reduced to the minimum entropy, i.e. a measure of disorder was growing, and the company eventually came to a standstill, to degradation. Here were used exclusively negative feedbacks that support homeostasis. To exit from the crisis, many businesses used the positive feedback, which leads, in the first stage to the destabilization of the system. In this case they used the new organizational forms (firms, joint stock companies, corporations, etc.); company to reduce local entropy more widely and effectively used external energy, matter and information, structure was complicated. The system accelerated the process of self-organization, and it began to evolve.

We have considered only fragments of a single synergistic process in the psychophysical open systems in their interaction with the environment. Role of anthropogenic factors in these systems is extremely high; moreover, their operation is greatly affected by the public laws, rules which are difficult to describing mathematically as they appear in the form of trends. In these cases, often use verbal description of the system: the objectives are usually defined verbally, and the laws of development are formed without the use of mathematical terms. The classic triad can be used, which exists in the theory of knowledge: observation and experience $\Rightarrow$ synthesis and conclusions $\Rightarrow$ check termination in practice. Or the same as used in the mechanics of management systems: information gathering $\Rightarrow$ stage of treatment $\Rightarrow$ stage of decision-making.

Considered in relation to complex technical systems dialectical chain of knowledge is as follows: the study of the system and the accumulation of information $\Rightarrow$ construction and study of physical (phenomenological) and mathematical models $\Rightarrow$ making inferences and using them in practice.

The construction of phenomenological models of the system is very important They have to adequately reflect the main parameters of its organizational structures and logical connections between them. By induction a mathematical model can be built. There is another way - a way of deduction, when the motion is carried out from general concepts to particular models that describe specific situations. In any case, the construction of formal models of the system is the possibility to carry out not only the analysis of the processes occurring in it, but also to solve

practical problems. In other words, well-built model allows a deeper understanding of the system structure, the skeleton of its organizational forms, the evolution of its development and degradation of individual structures. The model allows globally evaluate the dialectical unity of two contradictory existence of the system began – the evolution and degradation, preservation and destruction.

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Аннотация. Авторы рассмотрели современные научные подходы к проблеме устойчивого развития сложных динамических систем. Обобщены главные факторы риска: антропогенные, техногенные и экологические. Некоторые аспекты дарвиновской триады и второй закон термодинамики использованы для объяснения аспектов глобальной безопасности.

Ключевые слова: устойчивое развитие**,** сложные технические системы, техносфера, ноосфера, законы термодинамики

Анотація. Автори розглянули сучасні наукові підходи до проблем сталого розвитку складних динамічних систем. Узагальнені головні фактори ризику: антропогенні, техногенні і екологічні. Деякі аспекти дарвінівської тріади та другий закон термодинаміки використані для пояснення аспектів глобальної безпеки.

Ключові слова: сталий розвиток, складні технічні системи, техносфера, ноосфера, закони термодинаміки

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ЭКСПЕРИМЕНТАЛЬНЫЕ ИССЛЕДОВАНИЯ АМОРТИЗАТОРОВ СЛОЖНОЙ ФОРМЫ ДЛЯ ВИБРАЦИОННЫХ МАШИН

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ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ АМОРТИЗАТОРІВ СКЛАДНОЇ ФОРМИ ДЛЯ ВІБРАЦІЙНИХ МАШИН

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EXPERIMENTAL STUDIES OF SHOCK ABSORBERS WITH A COMPLEX SHAPE FOR VIBRATORY MACHINERY

Аннотация. В работе рассматриваются резиновые виброизоляторы со сложной формой свободной поверхности, предназначенные в качестве упругих звеньев для машин, которые в процессе эксплуатации испытывают стационарные длительные циклические нагрузки. Свободная форма поверхности виброизоляторов позволяет реализовывать весьма важную особенность – малую жёсткость в направлении силы и большую несущую способность. Экспериментально для конкретных элементов типа АР и ВР определены статические характеристики и распределение температуры диссипативного разогрева при циклическом сжатии. Приводятся формулы для расчёта жесткостных параметров элементов при деформациях сжатия и сдвига с учётом соотношения условных и истинных величин модулей Юнга и сдвига.

Ключевые слова: амортизатор сложной формы, зависимости сила-осадка, условный модуль упругости, истинный модуль упругости

В работе рассматриваются резиновые детали типа АР (амортизатор резиновый) (рис. 1, рис. 2) со сложной формой свободной поверхности. Такая форма позволяет при требуемой несущей способности получать малую сдвиговую жёсткость, а также предотвращать значительный саморазогрев упругих опор при работе в экстремальных условиях. Детали предназначены для использования в вибрационных машинах в качестве виброизоляторов и элементов упругой подвески и в процессе эксплуатации испытывают деформации сжатия от веса машины и деформации сжатия со сдвигом от возмущающей силы привода. Разработаны различные типы амортизаторов АР из резин серийных и опытных марок. Геометрические размеры исследуемых деталей приведены ниже; физико-механические характеристики некоторых резин приведены в [1, 2].

Тип элемента	Диаметр D, мм	Диаметр d, мм	Высота H, мм
АР103	120	72	148
ВР201.1	100	70	80
ВР201.2	100	76	80