Program of lectures of the Third School of Young Scientists «Monitoring of Natural and Technogenic Systems» November 22-24, 2021 Perm, Russia

Gendler Semen Grigorievich

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Monitoring of the radiation situation in underground structures located in radon-hazardous regions of Russia

Brief information about the physical properties of radon is given. The mechanism of its influence on human health is described. The principles of regulation of the radiation environment, including that in underground facilities, characterized by the presence of radon and its daughter products in the air, are described. The characteristics of the Russian territory in connection with radon hazard are presented, and the areas where underground objects are located in radon-hazardous areas are highlighted.

The peculiarities of radiation environment generation in uranium, metal and polymetallic mines, coal mines, underground structures not related to the extraction of minerals are described. Main processes that determine the mechanisms responsible for radiation environment generation in various underground objects are outlined. Particular attention is paid to the description of the factors affecting radon transfer in rocks and mine air, in long railway tunnels of the Baikal-Amur Mainline (Baikalsky, Severo-Muisky tunnels), in the St. Petersburg metro, and in the Yakovlevsky metal mine.

Approaches to selecting initial data for the analysis of a radiation situation are described. These approaches take into account the high radon intake into the air of mine workings and provide methodological support for determining the level of specific radon emissions. Mathematical models of radon transport in rocks and mine air are described, and the full-scale test results are compared with the results of calculations.

Methods for monitoring radiation situations in mine workings with high radon flow rates are presented.

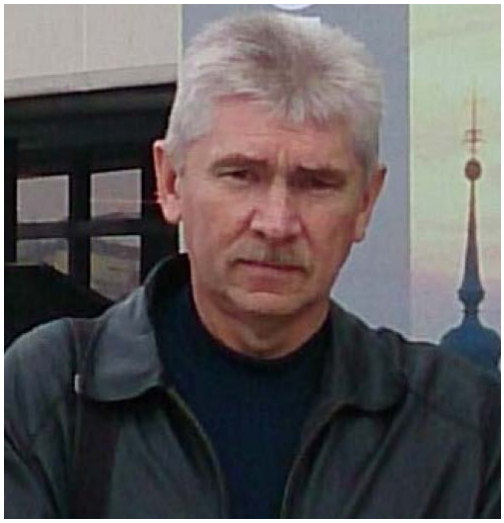
Using the example of the Baikalsky and Severo-Muisky railway tunnels, an assessment of the effectiveness of various measures used to normalize the radon situation in the extended mine workings of these tunnels is given.

Gladkovsky Sergei Victorovich

Doctor of Technical Sciences, Chief Researcher, Head of the Laboratory of Deformation and Fracture of the Institute of Mechanical Engineering of the Ural Branch of the Russian Academy of Sciences (Yekaterinburg). Research interests: structural aspects of deformation and fracture of high-strength and metastable steels and alloys, layered composite and meteorite materials, experimental fracture mechanics and fractographic analysis. Author (co-author) of over 300 scientific publications, including 95 articles in peer-reviewed scientific journals, 5 inventions, 2 textbooks and 1 collective monograph.

Monitoring of crack resistance of technical and natural materials under various mechanical loading conditions

The report provides the principles underlying the theory of experimental fracture mechanics and a brief history of its development. The main criteria of fracture mechanics for various loading conditions (statics, cyclic, dynamics) and the possibility of their use for assessing the resistance of materials to brittle fracture and predicting the reliability of products and structural elements by analyzing the critical crack length are considered. The values of the most important indicator of static crack resistance (fracture toughness) K_{1c}, obtained for of machine-building steels and alloys, non-metallic, composite and natural materials (ice, wood, meteorites), are presented. The well-known approaches to predicting the static crack resistance of metallic materials within the framework of micromechanical fracture models are analyzed. Possibilities of increasing crack resistance and structural strength of a wide class of materials and probable causes of their degradation due to unfavorable structural changes in products during their service are shown. Existing concepts of the unified physical nature of destruction of materials of various classes are considered from standpoint of synergetics and fractal geometry of fracture structure.



Kostin Vladimir Nikolaevich

Doctor of Technical Sciences, Associate Professor, Deputy Director for Research of the Institute of Metal Physics of the Ural Branch of the Russian Academy of Sciences (Yekaterinburg), Head of the Laboratory for Integrated Control Methods, Chief Researcher

Methods and tools for monitoring pipelines

To date, the planned potentials of most of the oil and gas facilities in the Russian Federation have been exhausted by 60-70 percent. 25 percent of gas pipelines have been in operation for more than 20 years, 50 percent - from 10 to 20 years, and 5 percent have generally exceeded the normative resource - 33 years. The indicators for trunk pipelines are also disappointing: over 30 years - 26 percent, from 20 to 30 years – 30 percent; from 10 to 20 years old - 34 percent, up to 10 years - only 10 percent. The main reason for failures of oil and gas facilities is corrosion damage. In Russia, 40-50 percent of machines and structures operate in aggressive environments, 30 percent in mildly aggressive environments, and only about 10 percent do not require active anti-corrosion protection. For infield oil, water and gas pipelines, 95 percent of failures are attributed to inline and external corrosion. Pipes from different manufacturers differ significantly in performance. In some cases, new pipes that are laid in the pipelines being repaired break down faster than those laid earlier. The main causes of accidents on main gas pipelines are external and stress corrosion (44.8% of cases). Other causes are as follows: operational damage; violation of conditions and operating modes; construction defects; defects in the manufacture of pipes and equipment; natural disasters. Therefore, monitoring the condition of pipelines develops, as needed, from a scientific and technical object to a production branch. The large length, aging, variety of operating conditions of pipelines and the high risk of their emergency failures pose a need for the development and expansion of the scope of application of physical methods and means of pipe quality control and pipeline diagnostics. The report analyzes the types and sources of pipe defects, indicates the factors that increase the service life of the pipes in use and describes the existing and promising physical methods and tools for pipe diagnostics both during manufacture and during operation.

Krivtsov Anton-Irzhi Mirislavovich

Corresponding Member of the Russian Academy of Sciences, Doctor of Physics and Mathematics, Director of the Peter the Great Higher School of Theoretical Mechanics of the St. Petersburg Polytechnic University (St. Petersburg). A. M. Krivtsov is a specialist in the field of mechanics of discrete media and media with microstructure, mechanics of deformable solids, computer modeling of mechanical systems. Author of over 150 scientific publications, cited more than 1400 times in total.

Dynamics of mass and energy

Wave energy transfer in an inhomogeneous chain of interacting particles is analyzed. The evolution of an arbitrary finite energy perturbation is studied. The analogy between mass transfer and energy transport is used to develop mathematical tools that allow the equations of classical matter dynamics to be used to describe energy dynamics. For energy bodies, effective mass, momentum, moment of inertia and other quantities characteristic of material bodies are used. The concepts of a carrier and a phantom are introduced, where the carrier is a medium capable of transmitting energy, a phantom is a virtual material body with a mass distribution proportional to the distribution of energy in the carrier. It is shown that phantoms for an inhomogeneous chain satisfy Newton's second law. For specific systems, constitutive equations describing the total force acting on the phantom are derived, and closed-form dynamic equations are obtained. It is shown that, by choosing the parameters of the chain in a certain way, one can derive the dynamic equation for the phantom in the gravitational field. Similar methods are used to study the dispersion of energy in a system. The transfer and dispersion rates are introduced to analyze the evolution of the phantom. It is shown that, depending on the rate ratio, a phantom can behave either as a wave or as a particle.

Applications of energy dynamics to describe processes in other areas of modern physics, such as quantum mechanics, electrodynamics, and general relativity, are discussed. A concept is proposed, according to which matter can be considered as a phantom in some carrier, which is a different entity than matter. The interrelationship between this carrier and the known models of physical space is discussed. On the basis of the concept just described, some open questions in modern physics have been qualitatively analyzed.

Markelov Yuri Ivanovich

Candidate of Physical and Mathematical Sciences, Head of the Laboratory of Ecological and Climatic Problems of the Arctic at the Institute of Industrial Ecology, Ural Branch of the Russian Academy of Sciences (Yekaterinburg). Research interests: monitoring of air pollution, modeling the spread of pollutants in the atmosphere, study of present-day climate changes.

Experience of ground-based monitoring of greenhouse gases in the atmosphere of Arctic latitudes

The understanding the mechanisms of climate change in connection with the ongoing processes in the Arctic is the issue of fundamental scientific interest and is important when discussing political and economic measures aimed at mitigating climate changes. Greenhouse gases are optically active components of the atmosphere, which, along with aerosols, have a key impact on the energy balance of the planet and provide its greenhouse effect. The study of the processes of entry, transfer, transformation, and removal of optically active atmospheric components is currently one of the main areas of research into the impacts that disturb the climate system. A key tool for obtaining objective information on anthropogenic and natural sources of emissions/sinks is monitoring, i.e., obtaining long-term in-situ observation series.

The report presents the results of monitoring greenhouse gases on Bely Island (Yamalo-Nenets Autonomous Okrug) using a measuring and computing complex based on the Picarro gas analyzer and the method of passive wind location of the atmosphere.

Nagovotsin Oleg Vladimirovich

Doctor of Technical Sciences, Deputy Director for Research of the Mining Institute - FRC of the Kola Scientific Center of the Russian Academy of Sciences (GI KSC RAS, Apatity, Murmansk region). Research interests: automated design and planning of mining operations, mining and geological information systems.

Digital tools for solving mining technology problems

The modern methods of engineering support of mining operations for solving geological, mine surveying and technological problems are based on three-dimensional digital models which provide information on the geometric dimensions of the object, spatial position, physico mechanical, technological and technical and economic properties of mining technology objects. The structure and composition of digital models and databases, software for creating and managing them, methods and tools for solving applied problems, methods for visualizing models and preparing technological documentation on their basis form a digital technology for working with spatial geotechnological information.

Modeling of mining technology objects and technological processes makes it possible to create digital twins of mining enterprises in order to solve the problems of designing and planning of mining operations, ensuring their safety, managing mining operations based on dispatching mining transport equipment, monitoring the movement of personnel and the state of the air environment. This, along with the widespread use of remotely controlled and robotic technology, creates conditions for the transition to minimally-manned technologies for extraction and processing of minerals.

Nazarova Larisa Alekseyevna

Doctor of Physical and Mathematical Sciences, Head of the Department of the Institute of Mining. ON. Chinakala SB RAS (Novosibirsk), specialist in the field of solid mechanics and mechanics of oil reservoirs, author of 221 scientific works, 5 monographs and 5 objects of intellectual property. L.A. Nazarova member of the Russian National Committee for Theoretical and Applied Mechanics, the International Society for Rock Mechanics, Program Committees of the international EUROCK symposia.

Technogenic seismicity and evolution of stress fields during the development of mineral deposits: modeling and experiment

Nazarova L.A., Nazarov L.A.

I. Hierarchical approach to the construction of geomechanical models of natural objects. A method has been proposed to develop a stepwise solution of boundary value problems based on the hierarchy of volumetric geomechanical models. Boundary conditions at the first (global level) are formulated on the basis of indirect (seismotectonic, geodesic) information about stress fields in the lithosphere. At the second (regional) and third (local) levels, this task is performed using the results of calculations made at the previous hierarchical level, which are refined according to in situ measurements of the parameters of geomechanical fields. The approach was implemented within the framework of such projects as "Central Asia and its framing", "Altai-Sayan folded region" and "Tashtagol iron ore deposit". For the last project a detailed geomechanical model was built and applied to describe the process of evolution of the stress-strain state during its development in 1978- 2018ю

II. Evolution of the stress field in the process of field development and technogenic seismicity. The statistical analysis of the characteristics of the spatial-temporal distribution of nuclei of dynamic events induced by mining made has revealed their correlation with the parameters of the stress state.. With account of mining plans and forward calculations of stress fields, the proposed approach, which was tested using the database of seismic events of the Tashtagolskoye field in 1989 2018, makes it possible to give a predictive quantitative assessment of the level of anthropogenic seismicity and spatial localization of sources of dynamic phenomena during the development of solid mineral deposits.

III. Reconstruction of the stress field of the geomechanical space of the field deposit by solving inverse problems based on tomographic data. An approach to the interpretation of mine seismic information has been substantiated. It can be used to reconstruct the stress fields in the rock mass at each stage of the field development. The approach includes: triaxial compressive testing of samples to determine the empirical dependence of the velocity of propagation of elastic waves on stresses; stratum tomography using a standard observation system and impulses from dynamic events (with energy exceeding the background level) as sounding signals; the formulation and solution of the inverse problem of determining the boundary conditions for the geomechanical model of the examined object, which uses, as the input data, the velocity field in the illuminated part of the stratum reconstructed as a result of tomography.

Laboratory tests of coal samples were carried out according to the Karman scheme, The approximation of test results made it possible to construct analytical dependences of the velocity of longitudinal waves on the axial stress and lateral pressure.

Numerical experiments carried out for a typical configuration of an underground space during conveyor mining of coal strata at the Vorkutaugol mines have shown that for the configuration of the observation system adopted at the mine facilities, an effective way to ensure the unambiguous solvability of the inverse problem, is to provide good illumination of those sections of the stratum where there is an increased spatial stress gradient.

Yarmoshenko Illia Vladimirovich

Candidate of Physical and Mathematical Sciences, Director of the Institute of Industrial Ecology of the Ural Branch of the Russian Academy of Sciences (Yekaterinburg), Head of the Urbanized Environment Laboratory. Research interests: ecological safety of the urbanized environment, geoecology, radiation safety, radioecology, radiobiology, radiation epidemiology. Author and co-author of over 180 scientific papers, 6 monographs.

Radon as a factor in human exposure

Radon is a naturally occurring inert radioactive gas that is all-pervasive in the environment. As a result of low air exchange, the content of radon and its daughter products in the building premises is significantly higher than in the atmosphere. On average, the volumetric activity of radon in residential premises is 50 Bq / m3, however, under certain conditions this value can grow up to several hundred Bq / m3. A high level of radon volumetric activity in the air can cause the development of lung cancer. Protection of a person against radon exposure in dwellings is an interdisciplinary problem, which is studied and solved within the framework of a whole spectrum of natural science disciplines - radiobiology, radioecology, geoecology, gas dynamics, structural physics and other sciences. The lecture will systematize data on human exposure to radon, obtained in recent years both at the IPE UB RAS and other scientific organizations.

Zakharov Valery Nikolayevich

Corresponding member of RAS, Doctor of Technical Sciences, Professor, Director of the Institute of Problems of Complex Development of Mineral Resources of RAS, Vice-President of the World Mining Congress. Research interests: geodynamic, gas-dynamic and hydrodynamic processes in technogenically changeable rock masses, geocontrol, forecasting and control of technological processes in physical-technical and physical-chemical geotechnologies. Author (co-author) of more than 200 scientific publications

Nature-like and convergent technologies for complex development and conservation of the Earth's interior

The Earth’s mining and processing complex plays one of the key roles both in destruction and pollution of all geospheres of our planet, and accumulation of solid wastes on the Earth's surface, the amount of which is not less than 65-70% of the total volume of extracted from the lithosphere substance. At the same time a great number of cavities and voids are formed in the Earth interior in the form of worked out mines and open pits, as well as technogenic disturbed rock masses, which inevitably leads to a change in the stress-strain state of rock masses, regimes of underground and surface waters, deformation and degradation of the daylight surface, which were balanced during previous epochs.

However, nowadays and in the foreseeable future, extraction of commercial minerals is the non-competitive necessity for the existence of the anthroposphere. Therefore, the preservation or irreversible destruction of the movable equilibrium in the natural environment, which has developed over geological time, depends on how the technologies for full-filled development of the Earth's bowels will be developed in the close-up and long perspective.

In the process of implementing a number of fundamental projects carried out long before the advent of the modern concept of "nature-like technology", a new scientific direction was created and developed based on the idea of structural and functional convergence of antagonistic components of natural and technical systems for the developments of mineral deposits.

For the main geological types of deposits, the possibilities and practical solutions to the problems of creation and application of convergent mining technologies are considered, and measures to ensure the safety and efficiency of deposit exploitation are discussed.

Marsavina Liviu

Full professor in Strength of Materials and Fracture Mechanics at University Politehnica Timisoara, Romania, Corresponding member of Romanian Academy. His main research interests are in the field of mechanics of materials, fracture mechanics and structural integrity and durability applied to different materials and structures. Prof. Marsavina has published more than 100 papers in peer – review international journals and about 70 papers in the proceedings of international conferences. Prof. Marsavina is Vice President of European Structural Integrity Society (ESIS) and Co - chairmen of Technical Committee 13:Education of ESIS. From 2020 prof. Marsavina is Honorary Member of Italian Group of Fracture (IGF) and ESIS Fellow. In 2021 prof. Marsavina received the Paolo Lazzarin medal from IGF. He is involved in several scientific editorial activities being member of the editorial board of Proceedings of Romanian Academy, Fatigue and Fracture of Engineering Materials and Structures (Wiley), Frattura ed Integrita Strutturale (Italian Group of Fracture), International Journal of Structural Integrity (Emerald), Materials Design & Processing Communication (Wiley).

Structural integrity of components obtained via Selective Laser Sintering (SLS)

The additive manufacturing (AM) is part of Industry 4.0. Now the AM is integrated in many industries due to limitless geometrical possibilities of the products and to relative reduced production time. Independently, the Selective Laser Sintering (SLS), as one of the AM technologies, uses a laser beam to selectively bound the powder particles together. The relation between technological parameters and mechanical, fracture and geometrical properties is very important to be known. Extensive mechanical and fracture tests, for fully characterizing the properties of samples obtained by SLS were performed. In addition, in what extend the obtained properties belong to the material or to the technology used for fabrication represents a major concern.

Susmel Luca

Professor of Structural Integrity of the University of Sheffield (UK). Since 1998 Luca has focussed his attention mainly on problems related to the static, dynamic and fatigue assessment of engineering materials and components. The work done in the above research areas has led to more than 250 scientific papers as well as to a book devoted to the multiaxial fatigue assessment (Susmel, L., Multiaxial Notch Fatigue: from nominal to local stress-strain quantities. Woodhead & CRC, Cambridge, UK, ISBN: 1 84569 582 8, March 2009). His scientific papers have attracted significant interest from the international scientific community, evidenced by an h-index of 33 with about 4.1k citations in total according to Scopus (h-index of 38 with more than 5.2 citations according to Google Scholar). He is a member of the Editorial Boards of the two leading international journals in the fatigue and fracture field, namely “International Journal of Fatigue” and “Fatigue & Fracture of Engineering Materials & Structures”. Luca is the Editor-in-Chief of “Theoretical and Applied Fracture Mechanics” (published by Elsevier) which is the top journal in the fracture mechanics field (Impact Factor=4.017).

Static assessment of notched additively manufactured polylactide (PLA)

The Theory of Critical Distances (TCD) is the name which has been given to a group of design methodologies that all make use of a material length scale parameter to post-process the local linear-elastic stress fields in the vicinity of the crack initiation locations. The aim of the present talk is to investigate whether the simple linear-elastic TCD is successful in predicting static strength of notched components made of 3D-printed polylactide (PLA), with PLA being a thermoplastic aliphatic polyester that is produced from renewable biodegradable resources.

Subsequently, an advanced approach based on the equivalent homogenised material concept and the Theory of Critical Distances is formulated to perform static assessment of plain/notched objects of polylactide (PLA) when this polymer is additively manufactured with different infill levels. The key idea is that the internal net structure resulting from the 3D-printing process can be modelled by keeping treating the material as linear-elastic, continuum, homogenous and isotropic, with the effect of the internal voids being taken into account in terms of change in mechanical/strength properties. This idea is initially used to assess the detrimental effect of the manufacturing voids on the static strength of the plain (i.e., un-notched) material. This is done by addressing this problem in a Kitagawa-Takahashi setting via the Theory of Critical Distances. Subsequently, this approach is extended to the static assessment of notched components of 3D-printed PLA, i.e., it is used to take into account simultaneously the effect of both manufacturing voids and macroscopic geometrical features.

The accuracy and reliability of the design methodology considered in the present talk is checked systematically against a large number of experimental data generated by testing, specimens of 3D-printed PLA. The remarkable level of accuracy being obtained strongly supports the idea that static assessment of 3D-printed materials with complex geometries and manufactured with different infill levels can be performed by simply post-processing conventional linear-elastic Finite Element (FE) solid models, i.e., without the need for modelling explicitly the detrimental effect of the manufacturing voids.

Program of master classes of the Third School of Young Scientists «Monitoring of Natural and Technogenic Systems» November 22-24, 2021 Perm, Russia

Mubassarova Virginia Anatolyevna

Candidate of Physical and Mathematical Sciences, Researcher of the "Institute of Continuous Media Mechanics of the Ural Branch of the Russian Academy of Sciences" - a branch of the Perm Federal Research Center of the Ural Branch of the Russian Academy of Sciences ..

Possibilities of computer X-ray microtomography technology in science and technology

The master class is devoted to the use of computerized X-ray microtomography for solving problems of fundamental and applied science and technology. The application of Computerized X-ray microtomography allows high resolution 3D imaging of internal microstructure of objects.

A compact Skyscan 1272 microtomograph (Brooker, Belgium), located at the test complex of IMSS UB RAS, a branch of the PFIC UB RAS, is equipped with a microfocus X-ray source and a detector - a 16-megapixel wide-format CCD matrix, and provides a submicron resolution in studying the structure of objects. The Skyscan 1272 microtomograph uses a 16-position changer for automatic scanning of objects and a range of platforms for mechanical tests in compression and tension, as well as heating and cooling platforms for studying temperature effects on the internal microstructure of objects.

Microtomography has a wide range of applications for visualizing the microstructure of objects, materials and media for the purposes of medicine, biology, archeology, soil science, mineralogy, mining and oil-extracting industries, as well as applied problems of materials science, including composite and innovative materials. Special attention will be paid to the problems of adjusting the scanning parameters, subsequent reconstruction, and 2D and 3D analysis.

The master class is focused on familiarizing students, graduate students of universities, and specialists of enterprises with one of the most advanced and actively improving methods of non-destructive testing of the internal structure of objects with a submicron resolution.

Yevseyev Anton Vladimirovich

Candidate of Technical Sciences, Researcher of the Laboratory of Physical Processes of Development of Georesources at the Mining Institute of the Ural Branch of the Russian Academy of Sciences - a branch of the Perm Federal Research Center of the Ural Branch of the Russian Academy of Sciences. Research interests: assessment of the stress state of rock masses, instrumental methods for monitoring the stability of mine workings. Author and co-author of over 100 scientific papers. Member of the International Society for Rock Mechanics (ISRM).

Instrumental methods for monitoring the stress-strain state of mine workings

One of the criteria for ensuring safety in the development of mineral deposits by the underground method is the compliance of the actual deformations of the bearing elements of the mining system to the design values. This requirement is especially important in the development of water-soluble ore deposits, where uneven subsidence of the underworked strata can lead to the formation of water-conducting cracks and the breakthrough of fresh water into mine workings. Regular monitoring and assessment of the stress-strain state of the rock mass allows reducing the emergency risks at the mining enterprise due to timely adjustment of the parameters of mining works and the application of the necessary mining technical protection measures.

The lecture will present various methods for controlling deformation processes around mine workings and methods for assessing stresses in the bearing elements of the mining system. The experience of organizing regular instrumental monitoring of the state of interchamber pillars left to support the underworked strata is illustrated by the example of mines at the Verkhnekamskoe potassium salt deposit.

Shulakov Denis Yurievisch

Candidate of Technical Sciences, Head of the Laboratory of Natural and Technogenic Seismicity of the Mining Institute of the Ural Branch of the Russian Academy of Sciences, - branch of the Perm Federal Research Center of the Ural Branch of the Russian Academy of Sciences.

Seismological monitoring of the Verkhnekamskoe salt deposit

Today, seismological monitoring is one of the most effective tools for controlling the processes associated with the geodynamic activity of the subsoil, both natural and man-made. The network of seismic stations on the territory of the Verkhnekamskoye potash-magnesium salt deposit has been developing since 1995 and today it is a complex hierarchically organized system that allows recording the widest spectrum of seismic events - from tectonic earthquakes occurring at a distance of thousands of kilometers to extremely weak signals associated with the destruction of mountain rocks in the vicinity of mine workings. This allows the data to be used to solve a variety of tasks related to the safety of mining operations: routine monitoring in the area of operating mines, detailed observations at potentially hazardous areas, monitoring emergency zones in real time, etc. To solve these problems, a low-power digital recorder has been developed, and utilized as a key element of monitoring systems both on the earth's surface and in mine workings. Software systems have been created to provide effective recording target seismic signals against the background of intense technogenic interference, as well as to determine the main parameters of their sources (coordinates of the source and the seismic energy released in it).