Цель. Применять для строительства морских сооружений буронабивные сваи большого сечения (диаметром от 620 до 1500 мм и более) с „жестким сердечником", чтобы они взаимодействовали с шельфовыми грунтами и воспринимали динамические нагрузки.

Методика. В лабораторных условиях исследованы свойства шельфовых грунтов и внедрены в них буронабивные сваи диаметром 30 мм длиной до 600 мм, теоретически обобщено поведение сваи в шельфовых грунтах при импульсивно-динамических нагрузках от вибраторов.

Результаты. Рассмотрены взаимодействия буронабивных свай большого сечения с „жестким сердечником" при динамических нагрузках с шельфовыми грунтами. При этом динамические нагрузки были приняты от технологического оборудования, машин и механизмов, а также от морских волн к морским сооружениям, с буронабивными сваями большого сечения с „жестким сердечником", которые передают динамические нагрузки шельфовым грунтам. Составлены расчетные схемы действия динамических нагрузок через сваи на грунт, построены графики σ~ε в фазе сжатия и фазе разжатия. Определены эффективное время волны сжатия, изменение давлений в фазе сжатия, отражения и разрежения в грунтовом массиве.

Научная новизна. Впервые предложены буронабивные сваи большого сечения с „жестким сердечником" использовать для строительства морских сооружений, которые позволяют получить значительную экономию арматуры по сравнению с обычными буронабивными сваями такого же сечения. Разработаны методы определения взаимодействия буронабивных свай большого сечения с „жестким сердечником" при статических и динамических нагрузках с шельфовым грунтовым основанием.

Практическая значимость. Применение разработанных методов позволяет оценить свойства щельфовых грунтов, выбрать рациональную конструкцию свайных фундаментов и их совместную работу или взаимодействие буронабивных свай большого сечения с „жестким сердечником" с шельфовым грунтом, что обеспечит устойчивость и долговечность морских сооружений.

Ключевые слова: *волновые процессы, буронабивные сваи с „жестким сердечником", волны сжатия, волны разряжения, упругие волны, упругопластичные волны, шельфовые грунты, давление*

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CREATION AND IMPLEMENTATION OF GEOLOGICAL AND ANTHROPOGENIC MODELS OF MINING SYSTEMS

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СТВОРЕННЯ ТА ВТІЛЕННЯ ГЕОЛОГО-АНТРОПОГЕННИХ МОДЕЛЕЙ ГІРНИЧОПРОМИСЛОВИХ СИСТЕМ

Purpose. Development of methods of geoinformation modeling of anthropogenic systems for raising the efficiency of mining operations.

Methodology. Building of anthropogenic models of mining enterprises and selection of efficient solution options using simulation modeling and GIS-technologies.

Findings. It was found that developed anthropogenic models enable to describe processes of mining operations to the fullest extent possible.

Originality. The research used the methods of simulation modeling and GIS-technologies in the building of anthropogenic models of mining systems enabling to ensure adequate model representation of the main facilities and processes of a mining enterprise.

Practical value. The main types of anthropogenic models have been developed as well as methods for running of simulation studies. As tested at a number of coalmines of Kuznetsk Basin they proved the possibility of their practical application.

Keywords: *anthropogenic models, mining systems, geoinformation modeling*

Geoinformation systems (GIS) are used in many fields of human activity. At the same time, a number of such fields and lines of the use of GIS are steadily on the rise. These systems are of particular importance in mining. GIS are used at all stages of mining systems:

- in the course of exploratory studies of the areas of the earth's crust
- in the course of geological exploration work
- in the course of commercial and operational exploration of mineral deposits
- in the course of designing of mining enterprises
- in the course of implementation of processes of mining works
- at the stage of temporary closing or liquidation of a mining enterprise
- for recording the effects of the operation of a mining system on the environment (natural objects).

It is natural that at every stage of creation and operation of various mining systems, the GIS, used and models of objects and processes, created with their help have their own purposes of use and specifics of building.

Our teams have been doing research in this area for over two decades. The following are the main scientific findings of the last years.

All GIS, used in mining systems [1], are designed for building a model of a mineral deposit. Models have many types and specific features, but all of them have to be open and object-oriented. Besides, it is desirable that the models created should be dynamic. Computer models of mineral deposits are generated layer by layer. The entire rock mass is represented as the aggregate of formations (layers) overlying on top of each other, located in a voluminous space and in a well-ordered and gapless manner within the crust section concerned. Every formation (layer) is comprised of a set of discrete elements. All discretes are shaped as prisms with a cross section in the form of regular hexagons equal in area. An aggregate of upper and lower bases of discretes of one formation represents roof and floor surfaces of the latter. Discretes of a multitude of formations, located on top of each other have a common vertical axis and their cross sections have the same orientation in space. Elements of each rock layer are built and positioned in space of a full model using conventional statistical methods (inverse distances, semivariograms, etc.), generating a dimensional model of a layer. For sections of deposits with a low degree of exploration, heuristic methods for building of discrete elements are used in a weak-link environment. Models of layers are deployed in a well-ordered manner corresponding to their geological age and are adjusted (smoothed out) for tight interlock with models of adjoining layers. As a result, a continuous model of the geological environment is formed to the extent of a section of a mineral deposit in question. Simultaneously with evaluation of geometrical (spacial) parameters of every discrete, quantitative and qualitative characteristics of rock types are determined which make up this element.

Such a complete detailed spatial and attributive description of the model enables to implement on its basis not only standard functions (such as building of geological plans and sections, calculation of mineral reserves, implementation of 3D visualization of mineral bodies, interface of the latter in space with technological facilities of mining enterprises, etc.) but also to build on their basis models of the 5^{th}level of anisotropy and higher (simulate rock fall processes followed by a coal miner face advance, gas emission in worked-out area, etc.).

It is known that systems used by man can be divided into *natural, technical and natural-technical.* **Natural systems** exist beyond the will and desire of man (land, seas, oceans, rivers, atmosphere, etc.). Modeling of such systems is reduced to the simulation of operation of their separate integral elements and subsystems in order to determine the laws of their development and ensure systematic use of various natural resources for the benefit of humankind.

Technical systems are entirely “a creation of mind and hand of man” (machinery, plant, mechanisms, facilities, etc). They have specific objectives, algorithms of operation and as a rule, closed structure. That is why models of such systems appear before their birth (creation) and serve in the future to optimize the performance of such systems and to obtain maximum utility functions thereof. Such models are most formalized and simulation results – most accurate.

On the other hand, in big (human-assisted) systems the most common are *compositions of natural and technical system (components thereof), a characteristic* feature of which is the invariance of ways and means which ensure their operation. Such systems belong to the class of underformalized systems and the processes of their operation are greatly influenced by the human factor. That is why such systems and the models which describe them may be called **anthropogenic**. Let us show that mining systems in question belong to this class of systems.

The main purpose of the creation and operation of a majority of mining systems is the extraction (production) of mineral resources and processing of mineral products, derived therefrom for use in the human activity. That is why such systems are tied to areas of the earth's crust (rarely to water or air areas), which contain mineral resources. In addition, many elements (subsystems) of these areas (*natural systems)* make part of respective mining systems. In order to get access to subsoil areas (blocks), *a system of mine openings and underground structures (*connected anthropogenic elements) is created, in which people and *engineering systems* (machinery and mechanisms as well as supporting subsystems: power engineering, transport, air-supply, dewatering, drainage, degassing and other subsystems) are housed and work. For this reason, such a big composite system, based on anthropogenic elements, belongs to the **class of anthropogenic systems**.

Operation of each geoinformation system yields both positive results (valuable mineral products) and negative ones (void formation, deformation of subsoil areas and land surface, emission (discharge) of pollutants into the atmosphere and hydrosphere, damage to biosphere within the boundaries of the mining allotment upon deployment of surface facilities of the enterprise, spoil dumps and infrastructure elements, etc.). Here is a rational use of system approach for creation and operation of any mining system. Here is why, successful and forward-looking mining enterprises use three classes of control assessment criteria, *efficiency (utility value), environmental friendliness, safety*.

It is evident, that creation and use of models in anthropogenic systems, where it is necessary to take into account the spatial arrangement and configuration, and, very often, the movement of individual elements, diversity and changeability of their parameters, requires use of special tools and systems, the best of which are GIS [2].

Let us consider specifics of the building of *anthropogenic models* for conditions of coal deposits. Obviously, described concepts can be applied to all other types of deposits of commercial minerals. However, in order to generate contrast-enhanced judgments, let us first consider the operation of enterprises, using underground coal mining method.

At present [3], a predominant number of geomodeling systems carry out building and analysis of the main (in terms of content of commercial components) naturally occurring elements of mining systems – beds of mineral resources or ore bodies. Models of mine workings are most often represented by layout maps of mining operations (projections of the main workings onto a horizontal plane or underlying bedrock of mineral resources, which host them). Axonometric 3D-models, which are used to a lesser degree, do not have a "tight" link with naturally occurring elements which host these workings. For this reason, such models are most often used only for approximate representation of the situation in the anthropogenic system. Decisions, due to insufficiency of information, are most often taken in an expeditious manner for local (in space) subsystems of a mining enterprise by top executives of this enterprise ("decision-makers") by means of judgment-based methods. Until now, a majority of mining enterprises have been using work order management systems.

Inconsiderable use of the existent geomodeling systems (including geoinformation systems) is explained by the fact that their development involves use of methods which are well-proven in engineering systems (such as military, space, industrial, transport, telemetry and other systems). In anthropogenic systems, which include naturally occurring elements and "purely man-made" elements and subsystems, which do not have "strongly-connected description", such methods are not enough. Besides, those of them, which do not take into account stochastic nature of attribute-based information on such elements (subsystems), objectively cannot be used for creation of anthropogenic models.

Big systems [4] are characterized by an inability to create for them a single universal model of their conditions and operation. Simulation is carried out using a system of models, interrelated in space and time with a various degree of detail in the description of objects and processes (scaling).

For example, in simulation of extension of a system of workings of productive mines by driving new and elongation of the existent workings, it is possible to build single-line 3D-models (tubes) with mapping of the dynamics of changes in the number and spatial characteristics of driven workings. Simultaneously, it is possible to build models of all driving faces at a larger scale with a more detailed description of objects (elements of a rock mass, engineering systems etc.) and work processes.

These models are characterized by an accurate description of spatial parameters of elements (surface) of mine workings based on the results of instrumental surveys, conducted periodically for separate areas of each working. In the course of mining operations' rearrangement of stress conditions in the elements of rock mass takes place, which results in their deformation and displacement. This, in its turn, gives rise to respective changes in spatial characteristics of areas of workings, driven in this rock mass. One has to rebuild models of workings to maintain the adequacy of their parameters to real parameters thereof, using the results of new instrumental surveys. In parallel, parameters of models of elements of engineering systems are being adjusted, which are deployed in these workings. Parameters of the elements of rock mass (primarily spatial parameters) are determined instrumentally using single exploration drill holes and wells, which are drilled irregularly with big scatter in time and space.

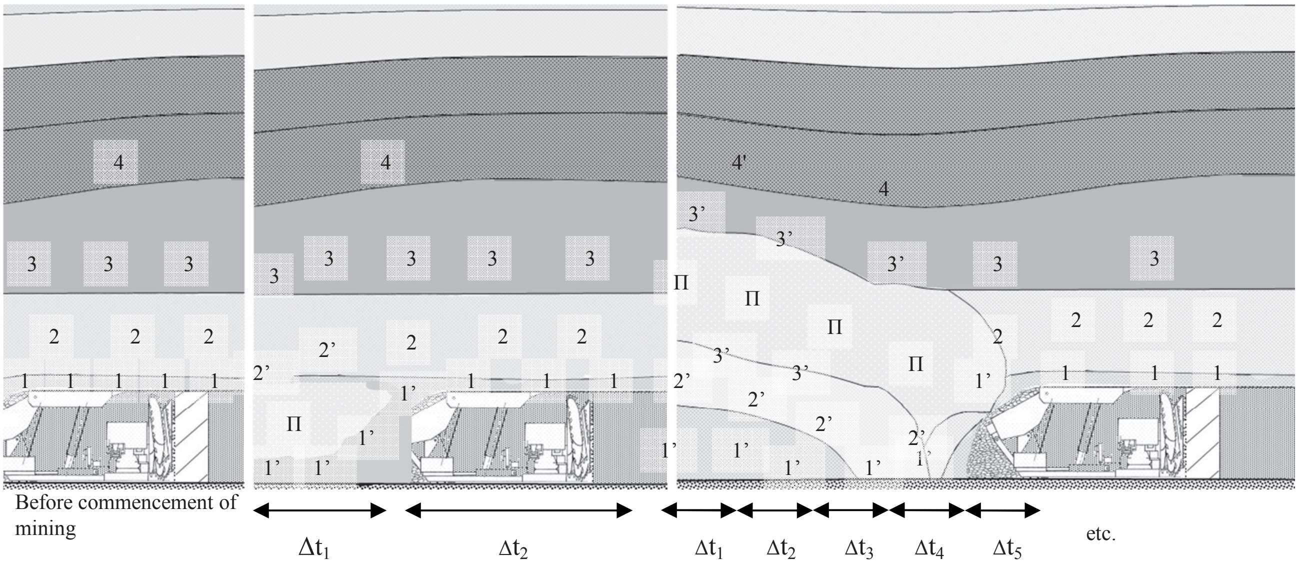
As a result, such anthropogenic models of rock mass with driven workings, housing equipment and facilities, will be most adequate to the described anthropogenic system to the extent of description of spatial parameters of workings and elements of engineering systems, deployed therein. Adequate model representation of other influencing para-meters of the anthropogenic system in question is possible only subject to joint building and study of the system of multiscale anthropogenic models using artificial intelligence methods.

The first developments in this field were implemented for simulation of change in the condition of rock mass upon underground coal mining directly in the area of second working/stope [5]. The diagram shows a model of generation of man-made objects (elements of mined-out space) out of the naturally-occurring elements of the environment in the process of second mining of coal in the longwall face.

In the process of coal recovery upon movement of a longwall set of equipment, an "empty" space is formed behind it. Blocks of overlying rock beds lose support from below, go out of equilibrium, crack, disintegrate, deform and fall in a random way one after another into open space. Upon un-tight filling of all this space, cracking and deforming blocks of overlying rock beds shift downwards, compressing and compacting the masses lying under them. Compacting processes together with shifting of blocks of an ever-bigger number of overlying rock beds gradually subside (most often with the formation of subsidence trough on the daylight surface).

To obtain numerical results, simulation modeling is carried out, using GIS-technologies. Stochastic data, required for modeling are generated for particular blocks, using fuzzy logic, on the basis of scattered in space experimental data (such as physical and mechanical properties of rocks in exploration wells and mine workings, spacial model of bed positions with indication of large tectonic disturbances, reference data on subsurface geology of the region etc.). The first experimental calculations were made for a number of stoping faces of coal mines of Kuzbas. They confirm a possibility of using this simulation method for forecasting the development of the mined-out area and its impact on the surrounding naturally occurring elements, technical and man-made objects. However, in order to increase the accuracy of obtained results, it is required to increase the number of determinants and create "a finer" simulation algorithm.

Given today's level of technical and technological equipment of coal mines and insufficient care about the environment, decision-makers show little interest in more informative description of the object of their activity. However, with the inevitable emergence of urgent need for full automation, and pretty soon, robotic automation of all processes of extraction of minerals, these modeling techniques will be very relevant and in demand.



Dia. Model of the process of generation of man-made objects out of natural objects:
1 – elements of beds "draw roof"; 2 – elements of beds of the main roof; 3, 4 – beds of overlying sets of rocks;
1',2',3' etc. – man-made elements; П – cavities

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Мета. Розробка методів геоінформаційного моделювання антропогенних систем для підвищення ефективності гірничого виробництва.

Методика. Побудова антропогенних моделей гірничих підприємств і вибір ефективних варіантів рішень із застосуванням імітаційного моделювання та ГІС-технологій.

Результати. Встановлено, що розроблені антропогенні моделі дозволяють найбільш повно описувати процеси гірничого виробництва.

Наукова новизна. Полягає у використанні методів імітаційного моделювання та ГІС-технологій при створенні антропогенних моделей гірничопромислових систем, що дозволяють забезпечити адекватне модельне подання основних об'єктів і процесів гірничого підприємства.

Практична значимість. Розроблені основні типи антропогенних моделей і методика проведення моде-

льних досліджень, апробація яких на ряді вугільних шахт Кузбасу підтверджує можливість їх практичного застосування.

Ключові слова: *антропогенні моделі, гірничопромислові системи, геоінформаційне моделювання*

Цель. Разработка методов геоинформационного моделирования антропогенных систем для повышения эффективности горного производства.

Методика. Построение антропогенных моделей горных предприятий и выбор эффективных вариантов решений с применением имитационного моделирования и ГИС-технологий.

Результаты. Установлено, что разработанные антропогенные модели позволяют наиболее полно описывать процессы горного производства.

Научная новизна. Заключается в использовании методов имитационного моделирования и ГИС-технологий при создании антропогенных моделей горнопромышленных систем, позволяющих обеспечить адекватное модельное представление основных объектов и процессов горного предприятия.

Практическая значимость. Разработаны основные типы антропогенных моделей и методика проведения модельных исследований, апробация которых на ряде угольных шахт Кузбасса подтверждает возможность их практического применения.

Ключевые слова: *антропогенные модели, горнопромышленные системы, геоинформационное моделирование*

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INFLUENCE OF METAL CASING ON THE ELECTRIC FIELD IN A CASED HOLE

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ВПЛИВ МЕТАЛЕВИХ ОБСАДНИХ ТРУБ НА ЕЛЕКТРИЧНЕ ПОЛЕ У СВЕРДЛОВИНІ

Purpose. To study the influence of metal casing parameters (casing conductivity and casing thickness) on the electrical field and the second derivative of potential in cased hole formation resistivity technology.

Methodology. The calculation formulas of the electrical field and the second derivative of potential were derived in multilayer media. Then the models of nondefective casing well and corrosion casing well were built in COMSOL soft. Moreover, both the electric field and the second derivative of potential were numerically calculated for nondefective casing well and corrosion casing well separately. Meanwhile, the influence of metal casing was analyzed.

Findings. The lower the conductivity of the metal casing is, the stronger the electric field and the second derivative of potential are; the electric field and the second derivative of potential are affected by metal casing parameters. These changes are always in close relation to corrosion defects in metal casing.

Originality. The models of cased hole were built in finite element analysis soft (COMSOL). The relation curve between the electrical field and casing parameters (conductivity and casing thickness) was obtained. The influence rule of metal casing was analyzed in detail.

Practical value. The results are applied to instrument design and logging interpretation.

Keywords: *electrical field, the second derivative of potential, corrosion metal casing, cased hole formation resistivity logging, cased hole model, COMSOL software*

Introduction. With Logging technology has been applied in the whole process of oil and gas exploration and development. The technology is an indispensable means of accurate oil and gas beds discovery and reservoir description, also provides important basis for reservoir determination, oil and gas reserves calculation, productivity evaluation and development planning, etc. Oil and gas reserves evaluation was based primarily on formation resistivity measurement, which has an irreplaceable engineering value for Hydrocarbons [1]. The traditional resistivity measurement was applied in open hole, and when the well was cased, compared with the formation resistivity, the metal casing resistivity was extremely small, therefore, the borehole resistivity logging instruments are not used in the casing well [2]. The cased hole logging is usually used in the old well, where the metal casing suffers from the high temperature, pressure and corrosion, defects such as holes, cracks, distortions, corrosions, fractures and collars will occur to the casing itself [3]. These defects influence the formation resistivity measurement, the logging response, when these defects are greatly serious, the logging data cannot be obtained, which makes the formation resistivity acquisition by logging interpretation impossible.

Previous research in this area includes as follows. In 1990, Kaufman [4] developed a theory to describe the elec-