The concept of creating perspective technological paradigm of formation (development) of the underground space on the basis of the leading development of new approaches in construction geotechnology and geotechnics. Premises and basic provisions (part 2)

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Abstract. The article presents some reasons for the lagging of domestic mining engineering from foreign competitors, substantiates the need to form a new promising technological paradigm in the field of formation and development of underground space. A new systematic approach to the development of geotechnics and geotechnologies is proposed, which allows for creation of prerequisites for formation of a new technological structure and Russia’s breakthrough into leading positions in the field of geotechnology and mining engineering.

The main areas of development of underground space include [1, 2]:

– adaptation of natural cavities (caves, karst cavities);
– reuse of existing man-made cavities (mine workings, mothballed objects of civil defense, etc.) in a new capacity;
– construction of new underground facilities for civil and special purposes.

The development of civilization is accompanied by the expansion of infrastructure and population growth, which inevitably leads to reduction of the amount of the undeveloped territories on the surface of the planet as well as search for new places to accommodate buildings, industrial and other objects of human activity.
In fact, there are three of such places [3, 4]: space, water bodies and the Earth’s interior, and subsequently the surface and the interior of other planets. At the present stage of development of our society, underground space is of the greatest interest.

Worldwide, the construction of underground facilities for various purposes has become one of the priorities [5]. The number of them in developed countries doubles every 10 years [3–5], and in the future we should expect a further increase in the rate of exploration of underground space.

The market for the construction of underground workings in Russia is growing dynamically. Growth rates in natural terms range from 9 to 27%.

**By function, underground facilities can be divided into four main groups [3, 4]:**

1. Industrial and infrastructure facilities for technical purposes (energy, mining and industrial enterprises, transport complexes, warehouses, etc.).
2. Social facilities (libraries, hospitals, commodity bases and storages, gyms, shops, etc.).
3. Objects for environmental purposes (repositories for the disposal of radioactive and industrial waste, hazardous substances, hazardous manufactures).
4. Objects of defense purposes.

The modern state of technology in the field of underground space formation by a mechanized method is represented by two classes of mining machines [7, 8]: tunneling machines and tunneling shields. At the same time, if the production of tunneling machines in Russia is somehow represented by Ltd Yurga Machine-Building Plant and JSC Kopeysk Machine-Building Plant, then the production of panel-tunnel mining aggregates is much more complicated, it simply does not exist.

In the USSR, tunneling shields were designed and manufactured by domestic enterprises. Import of such important equipment was almost absent [5, 7, 8]. In the late 90s, production was almost completely stopped due to the crisis in the economy of our country, scientific and design institutes were closed.

Russia has fallen into a situation in which it is extremely dependent on imports.

It should be noted that the world's first mining combines and sewage treatment plants for mining reservoir deposits were created and introduced in the USSR in the 40s and 50s. Further development and introduction of new equipment (not equipment upgrades) was a very long process.

The main types of products offered by foreign manufacturers for tunneling are: tunneling machines of all diameters for all rocks and environmental requirements, machines for driving in hard rocks, open tunneling machines with a system of thrust (Gripper) against the walls of the tunnel, tunneling machines for oblique tunneling, expansion tunneling machines, tunneling shields, tunneling machines, etc.

**Major competing companies [5, 8]:**

- **Herrenknecht AG (Germany).** It is the only company in the world that manufactures machines for the construction of tunnels with diameters ranging from 0.10 to 19 meters in any engineering and geological conditions;
- **The Robbins Company (USA).** An international organization with four main production enterprises, has an extensive network of representative offices throughout the world (at the moment there is no official representative office in Russia). Over 60 years on the market;
- **Mitsubishi heavy industries, Ltd (Japan).** Large diversified holding with a century and a half history (the company was founded in 1868);
- **Lovat Tunnel Equipment (Canada).** Engaged in the design, maintenance, production and repair of shield tunnel complexes, specializes in shield microtunnel complexes of diameter from 0.75 to 15 m;
- **WIRTH GmbH (Germany).** Produces equipment for laying and maintenance of tunnels, which is used throughout the world.

Currently, the introduction of fundamentally new domestic technology in coal and mining companies, tunneling organizations in Russia is almost impossible, since a prerequisite for its use is the customers' requirement to provide the results of using the machine in other enterprises. This is caused
by the discrepancy between the technical levels of the consumer and the manufacturer of technological machines, i.e. the destruction of the technological paradigm. (Paradigm – technological structure or Techno-economic paradigm is a set of related productions that have a single technical level and develop synchronously).

This makes impossible the revival and development of the mining engineering industry without restoring or creating a new promising industrial and technological paradigm.

At present, with the active participation of Ltd "Siberian NPO", the Concept of creating a promising industrial structure based on the priority development of key engineering components has been formed and is being implemented. One of the approaches of the Concept is the thesis [9]:

"It is difficult to enter the industrial structure formed by global corporations with standard products, but one can set a goal to replace this structure to the maximum extent. If we propose more economical technologies, we can significantly expand our participation in the international division of labor, as well as ensure our priority in creating more advanced mechanisms and machines."

A constraining factor in creating a promising industrial paradigm in the part relating to mining engineering, both in Russia and abroad, is the current approach to the creation of mining machines.

The traditional representation of excavation as the process of cavity formation in the rock massif, has always defined and still defines the directions of:

– scientific research;
– improvement of geotechnologies for the construction of underground structures and, accordingly
– creation of tunneling equipment for the formation of underground space.

At present, in underground conditions, the following external propulsive devices are used to move the tunneling apparatus: tracked, wheeled, wheel-rail or distance-walking. The propellers that have performed well when working on the earth's surface (at the contact of solid and air environments) are not adapted for movement in geoenvironment.

In the course of work of the tunneling machine or the shield, in order to create the force of thrust and pressure force on the executive body, the external geoenvironment itself is not involved in any way, what involved is only the solid surface of the excavation at the interface of the geo-and air environments, or with the shield method of penetration – a strong permanent support.

This circumstance leads to the main problems of modern technologies for the construction of underground workings:

– the impossibility of creating a universal mining apparatus capable of moving in any direction of the Earth’s interior;
– the dependence of the maximum force on the gravity vector, and as a result, the impossibility of creating large pressure forces on the executive body to destroy hard rock.

As a result, in order to create sufficient pressure forces, designers are forced to increase the mass of mining combines, the mass of which already exceeds 130 tons, and the task of reducing the overall metal consumption of the machine is not even considered.

Further development of work in the field of geotechnologies and geotechnics can go in two directions [2, 6]:

1) modernization of the existing mining equipment and its improvement by creating systems of a new technical level;
2) the search and creation of a fundamentally new, alternative geotechnological tools (technologies, geotechnics) for exploration of the subsoil and formation of underground space.

Known technologies for mining, developing along the path of increasing the power and metal consumption of equipment, have practically exhausted their capabilities in increasing productivity, ensuring safety of work and expanding the scope.

In search of ways to create a fundamentally new tools for mine workings, the team of authors reviewed alternative approaches and solutions used, in particular, in aircraft construction and
shipbuilding. As is known, in these areas results of the research based on the process of studying the motion of a solid body in air and water, respectively, are used.

Aircraft designers and shipbuilders in the design and construction of vehicles intended for movement in airspace (aircraft, helicopter, etc.) and in the aquatic environment (ship, submarine, etc.) found the possibility of using the environment itself to create thrust when the corresponding device moves. For this purpose, propellers operating inside the environment (propeller, propeller screw, etc.), or “into coverage” of the environment (water jet and other jet propellers), performance of which does not directly depend on gravity, were created. As a result, the possibility of moving a solid body (apparatus) in any direction of the air or water space was created.

Over the years, a team of scientists and engineers has been working to create a fundamentally new type of mining equipment – geokhodes [10–39].

A scientific and practical groundwork has been created in the field of developing new technology for mine workings [10, 11], and a new type of mining technology [12–15], the patent purity of the developed technical [15–24] and technological [11, 25-29] solutions has been confirmed.

With the participation of employees of UT I TPU, OJSC "UMP", KuzSTU, OJSC Siberian NPO and OJSC "KORMZ", the Comprehensive Project “Creation and Production of a Multi-Purpose Screen Tunneling Units of Geological Multipurpose Objects” was implemented - the winner of the Ministry of Education and Science (2013-218-04) in the selection of organizations for the right to receive subsidies for the implementation of complex projects for the creation of high-tech production [12, 13].

The accumulated scientific background allowed the team of authors to implement a complex of research and developmental works, which resulted in a prototype model of geokhod “model 401” (figure 1) [14].
The results obtained not only opened up new areas of research in the field of mining and determined the need for the emergence of a new branch of engineering – geo-engineering, but also created the prerequisites for Russia to become a leader in the field of geotechnology and mining engineering.

Patent search and analysis of scientific publications showed that the research team is a leader in this direction. There are no analogues of the research conducted in mining and the results obtained both in Russia and in the world yet.

During the designing and manufacturing of the prototype, the absence of a domestic component base for many components was revealed, which, along with the imposed sanctions, will be a deterrent when creating new samples of geokhods.

In addition, there are no specialized centers for testing developed new geotechnics, its fine-tuning and implementation at existing enterprises.

The implementation of the project gave as a result not only a prototype of the machine, but also revealed new ways to improve the design of the geokhod, problems of testing and experimental studies of this type of machines, problems of creating a working environment for mastering the production of new types of products. The results obtained form the basis of innovative geotechnical tools for the formation of underground space – a complex that includes:

- a new approach to the conduct of underground mining and the formation of underground space;
- new technologies for underground mining;
- new class of mining technology;
- a new type of support for mine workings and lining of underground structures;
- new scientific and methodological support.

A new approach to the underground mining and the formation of underground space – the excavation of underground mining is considered as a process of movement of a solid body (equipment) in the environment of surrounding rocks (geological environment).

The marginal array (geoenvironment) is used here:
- as a supporting element involved in formation of the driving force of the underground vehicle – geokhod, incl. for the formation of a pressure force on the executive body;
- for the perception of reactive forces during the movement of the tunneling unit (underground apparatus);
- to perform basic technological operations, including fixing the production of a permanent support.

New technologies for underground mining – geo-technology – the process of mechanized mining with the formation and use of a system of marginal screw and longitudinal channels in which operations for the development of the face, cleaning the rock mass, fixing the open space, and moving the entire tunneling system to the face are being done in combined mode.

A new approach to the underground mining and the formation of underground space

New class of mining equipment, systems (GPS) – geokhods, underground robots.

Geokhod is a machine moving in the rock array using geological environment. The basic element of geokhod technology. Representing a new class of mining machines, geokhods are designed for driving underground workings for various purposes and location in space.

Underground robots. In the line of robots for various purposes, there are aircraft, ground, floating and underwater robots. There is an urgent need to create underground robots, especially for performing specialized tasks of the Ministry of Emergency Situations and other in dangerous and hazardous conditions. The principle of geokhod operation assumes fully automatic control of the entire system. According to experts of the Ministry of Emergency Situations geokhod is the closest to the appearance of an underground robot.

A new type of lining of mine workings and lining of underground structures is a geo-built (marginal) support.
**Geo-built (marginal support)** is based upon the use of screw and longitudinal channels behind the contour of the current generation for formation of a spatial support system “support – marginal array of rocks”.

**New scientific and methodological support** – new scientific disciplines, educational programs, methods of substantiating the parameters of the main systems of geokhod and geo-built support, etc.

The solution of problems of designing a new type of mining equipment – geokhods– requires the creation of new scientific directions:

– geodynamics of underground devices is a science that studies the forces arising on the surface of a solid (underground device) moving in a solid environment (geological environment);

– geokhod engineering is a scientific discipline related to the design and construction of geokhods (underground robots).

One of the defining directions for the development of mining (development of the subsoil and formation of underground space) is the improvement of its **design and technological tools**, which in turn is based on specialists, scientific and engineering personnel and scientific and methodological support.

**Findings:**

– The introduction of a fundamentally new domestic technology in coal and mining companies is almost impossible in Russia, since a prerequisite for its use in the enterprise is the requirement to provide the results of using the machine in other enterprises.

– The current state of technology in the field of underground space formation in a mechanized way is represented by two classes of mining machines: tunneling machines and tunneling shields. At the same time, if the production of tunneling machines in Russia is somehow represented by Ltd Yurga Machine-Building Plant and JSC Kopeysk Machine-Building Plant, then the production of panel-tunnel mining aggregates is much more complicated, it simply does not exist.

– In Russia, with the active participation of OJSC Siberian NPO, the Concept of creating a promising industrial paradigm based on the priority development of key engineering components has been formed and is being implemented.

– Known technologies for mining, developing along the path of increasing the power and metal consumption of equipment, have practically exhausted their capabilities in increasing productivity, ensuring safety of work and expanding the scope.

– A new approach to the process of construction of underground workings and the formation of underground space has been formulated – the excavation of underground workings was initially considered as a process of movement of a solid body (equipment) in the environment of surrounding rocks (geo-environment).

– A scientific and practical groundwork has been created in the field of developing a new technology for mine workings, and a new type of mining equipment – geokhod.

– Many geokhod systems have no analogues in mining engineering, they are fundamentally different in purpose and principle of operation from all existing systems of mining tunnels and tunneling shields. In addition, the manufacture of geokhods and their systems are very specific in production.

– The results obtained not only opened up new areas of research in the field of mining and determined the need for the emergence of a new branch of engineering – geo-engineering, but also created the prerequisites for Russia to become a leader in the field of geotechnology and mining engineering.

– The absence of a domestic component base for many components has been revealed, which, along with the imposed sanctions, will be a deterrent when creating new samples of geokhods.

– There are no specialized centers for testing the developed geotechnics, its fine-tuning and implementation at existing enterprises.

– One of the defining directions for the development of mining (development of the subsoil and formation of underground space) is the improvement of its **design and technological tools**.
There is an urgent need to create a promising technological paradigm for the development (formation) of underground space based on the rapid development of new approaches in building geotechnology and geotechnics.

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