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Editorial

Mining Technologies Innovative Development II: The Overview

Sergey Zhironkin [1,2,*] and Dawid Szurgacz [3]

[1] Institute of Trade and Services, Siberian Federal University, 79 Svobodny Av., 660041 Krasnoyarsk, Russia
[2] Open Pit Mining Department, T.F. Gorbachev Kuzbass State Technical University, 28 Vesennya St., 650000 Kemerovo, Russia
[3] DOH Hydraulics Center, Polska Grupa Górnicza S.A., ul. Powstańców 30, 40-039 Katowice, Poland; dawidszurgacz@vp.pl
* Correspondence: zhironkinsa@kuzstu.ru

Dear colleagues—readers and authors of Energies journal, we present the Special Issue "Mining Technologies Innovative Development II", which continues the previous issue, developing the ideas of sustainable mining of fossil energy sources, concentrating around the innovative modernization of the mineral resource sector in the context of achieving sustainable development goals [1].

Today the innovative development of fossil energy sources mining coincides in its imperative with the expansion of renewable energy production [2], bringing modern society closer to a low-carbon economy, thanks to post-mining and full extraction of minerals and their recycling. The research development in the field of convergence of mining, digital, nature-saving and managerial technologies is currently taking place within the framework of Tripple and Quadruple Helix—new forms of implementation of innovative cooperation between firms and universities, local communities and governments [3]. In this regard, the Special Issue "Mining Technologies Innovative Development II" aims at creating a discussion platform for the global dissemination of advanced scientific ideas in the field of sustainable and innovative development of the mining sector.

The success of mining innovative development as a part of the global transition to sustainable development is determined by interdisciplinary research that combines innovations in the extraction of traditional fossil fuels, the production of energy from alternative sources, in geophysics and geochemistry, and information technology. Therefore, collected papers have contributed to the transition of mining to the circle of sectoral leaders in innovative development.

Like the previous one, the current Special Issue "Mining Technologies Innovative Development II" aims to progress the pluralism in the discussion of the problems concerning increasing the contribution of the mining sector to sustainable development by bringing together representatives of the research community from different countries.

Below there is a summary of each article in the Special Issue "Mining Technologies Innovative Development II", which underwent a thorough peer-review and was selected by the Editors from a number of publications devoted to solving the most urgent organizational, technical, technological and environmental problems of mineral resource sector development.

A. Wróblewski, A. Macek, A. Banasiewicz, S. Gola, M. Zawiślak, A. Janicka in their article consider a model of mining equipment operator's cabin using CFD analysis of the forced airflow and temperature distribution in the air [4]. The authors rightly assert that the primary temperature of rocks is the main source of thermal airflow, but diesel engines of mining equipment are an equally important source of heat. Therefore, the cabin geometric model proposed in the article takes into account heat transfer, according to three conditions: the current actual temperature, the predicted temperature of the conditioned air, and the

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simulated flow rate to ensure the thermal comfort of the operator. The achievement of the authors is the calculation and analysis of the personal mean vote (PMV) index. With its help, a conclusion was made about the optimal parameters of conditioned air (flow rate 2.4×10^{-2} m^3/s, temperature 10.00 °C) for the temperature in the mine working of 35.00 °C; the air temperature in mining machine cabin will be 20.40 °C. In turn, if the air temperature in the mine working rises to 38.00 °C due to increased heat release from the rock array or more powerful machine, it is required to lower the temperature of the conditioned air to 8.00 °C or increase the flow rate to 3.14×10^{-2} m^3/s. In this case, the thermal comfort of the operator in the cabin will correspond to a constant value of the PMV index.

The article by M. Pikuła, K. Chudy, M. Worsa-Kozak, M. Czop presents the results of the analysis of the deep-lying rocks hydraulic parameters, in relation to the deepening of mine shafts [5]. As the main method, the authors used an assessment of the drainage potential of Triassic sandstones during the analysis of core parameters. The authors proved that laboratory tests underestimate the hydraulic parameters of porous-fractured rocks, while the part of all core samples with the maximum value of hydraulic conductivity can be representative of the aquifer. Along with this, the authors showed that the currently used methods for calculating the water inflow to the mineshaft are characterized by low accuracy and reliability due to unrepresentative values of hydraulic conductivity. Therefore, the clarification of hydrogeological conditions when predicting the inflow to the mineshaft largely affects the pace of its construction, labor safety and safety of capital investments. Based on the results of laboratory studies and calculations, the authors recommend using the highest values of hydrogeological parameters of rocks based on a pessimistic scenario for predicting water inflow to conducted mineshafts. As a limitation of the study, the authors highlighted the applicability of the proposed method exclusively for porous and porous-fractured rocks.

A. Banasiewicz, P. Śliwiński, P. Krot, J. Wodecki, R. Zimroz presented a 4th order statistical polynomial model for 11 and 10 input variables with modeling accuracy of 8% and 13% respectively (measurements were carried out using SYN-APSA systems) in their article devoted to forecasting emissions of nitrogen oxides (NOx) by diesel transport vehicles in mines [6]. For comparison, the authors consider sensor accuracy of 10% and 20% for stable and transient operation modes. The importance of the study is confirmed by the fact that as the mine workings deepens and the mining front moves away from the ventilation shafts, the gas content increases, and the risk of reaching critical values increases. According to the results of the study presented in the article, flexible planning of the ventilation system is possible to optimize the consumption of electricity by transport and other mining equipment in deep underground workings. The authors rightly position the developed model as a "soft sensor", promising for monitoring and predicting NOx emissions from diesel vehicles, including dump trucks that are not equipped with harmful gas sensors, as well as for providing faster ventilation of underground mine workings along which diesel locomotives move.

The original method for detecting blockages of the belt conveyor transfer point was proposed by P. Bortnowski, H. Gondek, R. Król, D. Marasova, M. Ozdoba [7]. This method is based on the use of RGB camera for data acquisition and CNN Autoencoder for data analysis and interpretation. The authors proceed from the need to solve the widespread problem of failure of the transfer point of the conveyor belt due to clogging of the transfer chute and disruption of the flow of material by oversized pieces of rock or other objects, as a result of which the entire transport route can be disabled. In this regard, the use of a neural network allows restoring images of the operation of conveyor equipment for comparison with standard operating conditions. The authors concluded that the best results are possible when using Gaussian filters for image selection, thresholding and transformation using morphological operators. In particular, the neural network quite accurately detected transfer point blocking when oversized pieces of rock and anchor bolts hit (the most common reasons for a decrease in conveyor throughput). It will be useful for

readers to know that the future research of the authors promises to be focused on real-time processing of RGB images using a neural network.

D. Szurgacz, B. Borska, R. Diederichs, A.J.S. Spearing, S. Zhironkin in their article consider new possibilities of internal leaks minimizing in hydraulic prop of a powered roof support [8], starting from its three functions: equipment control, overload protection—the result of rock pressure, minimization of leaks in props and in entire hydraulic system. To do this, the authors propose replacing the existing support block with a double block with charging, which allows increasing the load capacity of the prop by 10–50% by maintaining pressure in the under-piston space of at least 250 bar. The leakage also can be minimized. The authors found that the block prototype maintains the required load capacity of the props, despite leaks, which makes it possible to avoid costly and time-consuming replacement of the props. The article presents the results of bench tests of the prototype block, which confirmed the correctness of the working hypothesis, as well as tests in real conditions, which approved the authors in the assumption of the operability of the power support prop in case of an internal leak. Consequently, the results of the study of double block with charging, presented in the article, allow replacing existing blocks in the real conditions of mines already today.

A. Smirnova, K. Varnavskiy, F. Nepsha, R. Kostomarov, S. Chen in their article consider the use of methane from coal mine as a primary energy source for power supply of mine consumers and, above all, data processing centers [9]. The authors rightly point out that the development of coal deposits by the underground mining releases up to 8% of methane into the atmosphere (the contribution to greenhouse gas emissions is up to 17%). In this regard, the authors proposed the integration of methane extraction from coal seams with the development of mine data centers (concept "Coal-Energy-Information") in three variants. They are cogeneration—burning the methane at gas power generating utilities; burning for use in absorption systems for data center equipment cooling; trigeneration—the use of power generating unit and absorption refrigerator for power supply to mines' data centers. As a result of a comparative analysis of capital and operating costs, profitability and savings for each option, the authors determined the payback period for investments: five years for the first, seven years for the second and six years for the third variant. This made it possible to single out the cogeneration of electricity from coalmine methane as the most promising way to supply power to data centers at mining enterprises. There is no doubt that the implementation of the author's idea will allow coalmines to enter the information technology market and diversify their activities.

M. Siami, T. Barszcz, J. Wodecki, R. Zimroz consider design and prototyping of the infrared image processing pipeline for robotic inspection, designed for monitoring conveyors at surface mines [10]. The authors rightly argue that traditional methods of transport equipment inspecting are laborious and dangerous, which fully applies to the thermography of intensively operating units. On this basis, the article considers a robot inspector moving along a conveyor, receiving, processing, analyzing and interpreting infrared images for automatic detection and analysis of overheated rollers. The authors identified significant potential for timely recognition of temperature anomalies analyzed using a histogram of infrared images obtained by the robot. The authors declare a limitation of the proposed method associated with false thermography results obtained from a mirror object in the RGB shooting field, which can lead to false alarms. The authors see overcoming the limitation in the use of pre-processing algorithms, including CLAHE, adaptive gamma correction to reduce unwanted gray level variations. The authors associate future research in this area with the widespread introduction of robotic devices and infrared image scanners in conveyor systems equipped with artificial intelligence for the transition to new synthesis methods.

The problem of underground structures geometry evaluation was considered by A. Wróblewski, J. Wodecki, P. Trybała, R. Zimroz in the context of using point cloud data for multivariate parameterization and multidimensional analysis [11]. Without a doubt, the implementation of underground mine workings and large-scale structures (gallery, bunkers,

chambers) in strong rocks by drilling and blasting or mechanically leads to the formation of surfaces that are uneven in terms of geometry. In addition, the resulting vibrations and seismic phenomena violate the stability of previously created structures. At the same time, it is difficult to use stationary underground monitoring systems due to the constant blasting, operation of mining and transport mining equipment. In this regard, the authors proposed an original method for monitoring the geometric parameters of underground workings, based on measurements using LiDAR/Terrestrial Laser Scanner. The resulting digital point cloud is used to create a 3D model of the tunnel geometry, processed repeatedly to obtain a homogeneous structure, followed by segmentation to separate cross sections with the required resolution. An important achievement by the author is the standardization of the operational structure of 3D data, which simplifies data analysis and reduces their required volume, and significantly increases the efficiency of post-processing.

The article by J. Janus, P. Ostrogórski is devoted to the modeling of underground mine workings using data obtained from laser scanning, in comparison with manual measurements [12]. The paper discusses the advantages and disadvantages of several methods for measuring the cross-sectional area of a mine working: the empirical method; use of CAD; approximation by a semi-ellipse, including those with attached straight sections. It has been established that the use of CAD software gives the best approximation than other methods. The results show the maximum differences between the semi-ellipse and laser scanning methods, and the approximation method at the level of 5.9%. The authors argue that in all methods the shape of the lower part of the working is modeled as a straight line, which often leads to an unacceptable simplification, therefore, for the deformed floor, it is recommended to take into account its height marks. This allows adjusting the length of the straight parts of the arc for better modeling of the shape of an underground mine working. Finally, the article convincingly proves that the use of the entire family of CAD methods makes it possible to speed up the modeling process, in particular, calculations of the cross-sectional area of mine workings. At the same time, for modeling each individual mine working, it is necessary to make a decision on the choice of an appropriate method, which is dictated by the inevitable deformations of the tunnels under the action of rock pressure and seismic effects.

A. Wróblewski, P. Krot, R. Zimroz, T. Mayer, J. Peltola in their article provide a detailed review of the energy-saving and environment-friendly solution for linear electric motor hammers [13], which are widely used for crushing oversized pieces of blasted rocks, as well as for disintegration of concrete structures. Today, along with electric hammers, hydraulic hammers are widely used, which have their own advantages and disadvantages. In this regard, the article provides an overview of existing hammers with a linear electric motor in order to select more energy-saving and environmentally friendly equipment. The authors argue that the shorter payback period of electric hammers (1–2 years) makes them especially profitable in enterprises with a large fleet of machines. However, their operation requires additional costs for the purchase of cables and power points, which, due to their versatility, can be used in enterprises for other purposes. The authors set promising scientific tasks for future research on electric hammers, related to the improvement of their design for use at elevated temperatures and humidity in underground mines, where full maintenance of machines is difficult.

Y. Yang, X. Xu, C. Wang in their article, devoted to forming an approach to the study of host rocks deformation in the development of coal seams [14], note that the mechanism of rocks deformation during the close mining of coal seams in coal mines is not sufficiently reflected in the studies. Therefore, the authors proposed a model for studying the distribution of stresses at different distances between deformation zones. The article presents the results of a significant number of measurements of rock pressure, which indicate that the degree of damage to a single column in the workings of the upper and lower coal seams is quite low (no more than 5% and 1%, respectively). With a roof settlement in the upper layer of the stratum in the range of 0.74–1.33 m, the authors revealed the occurrence of sliding instability. Accordingly, if the size of the subsidence exceeds the

values of 1.33 m, the massif within the underground mine working will be deformed, causing an increase in rock pressure. The staggered distance of 40 m between the upper and lower faces allows reducing the pressure on the face when mining the lower coal seam. Without a doubt, the results of the study presented by the author are the contribution to improving the method of reducing damage to underground mine workings and stabilizing coal production.

Feeling proud for the opportunity to participate in the editing of the Special Issue "Mining Technologies Innovative Development II" and select the best articles, it is necessary to thank all the Reviewers, whose work has allowed strengthening the expression of scientific thought in the field of sustainable development and mining–important modern energy carriers. One can be sure that further progress in the field of energy supply in modern economy and society will be stimulated by the popularization of innovative ideas and know-how in mining.

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