Abstract of the dissertation in the form of a series of publications entitled: Modeling processes in mining and geology using stochastic processes

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The purpose of this research was to develop mathematical methods and models describing selected technological processes that occur in mining. In the era of the IoT (Internet of Things), sensory technologies make it possible to acquire data on a wide range of phenomena, including data considered in this research work such as vibration data, data from onboard machine monitoring systems, gas concentration data, or seismic signals.

The technological processes or natural phenomena involved in mining are specific and require individual approaches. This dissertation is focused on four areas, i.e. on processes related to: vibration diagnostics in drive systems (predictive maintenance), ventilation of mines, efficiency management of self-propelled underground machines, and rock mass activity detection of P-waves in seismic signals. These processes can be described using random process models and statistical methods. They require advanced mathematical techniques for signal validation, processing, analysis, and statistical inference.

Research carried out to date in the field of machine diagnostics has demonstrated that the available tools/methods are not sufficient in the case of processing signals from mining machinery, in particular from a rolling bearing of a copper ore crusher. Therefore, a new method based on the conditional variance was proposed, which proved to be superior with respect to many commonly used methods in the field of machine diagnostics, especially for signals with non-Gaussian noise (when noncyclic impulses related not to the fault but rather to the technology of machine operation dominate over cyclic impulses related to the local fault). The dissertation demonstrates that the conditional variance approach is simple to implement and much more robust to different specifications of the problem, such as the ratio of cyclic to noncyclic impulses or their amplitude ratio.

Several diagnostic methods were tested in this study. One of the most advanced methods is the infogram, which allows diagnostic information to be selected on the basis of entropy analysis in the time and frequency domains. However, the infogram was found to be ineffective in diagnosing local damage in the case of data from a copper ore crusher. Simple modifications applied to the infogram were proposed to improve its effectiveness.

Alternative measures of dependency for local damage detection were also proposed. In the case of non-Gaussian noise, they show higher robustness than the popular approaches do. Their effectiveness was investigated for different simulation signals (with Gaussian/non-Gaussian noise) and for actual signals from a copper ore crusher and from a conveyor belt.

The dissertation also analyzes concentrations of selected dangerous gases in the deep underground mine, i.e. hydrogen sulfide and carbon monoxide. This is one of the first such investigations (based on long-term data) in Poland. It demonstrates that carbon monoxide concentration can be modelled by a mixture of deterministic and random components. It also demonstrates that the detected high values of carbon monoxide concentrations (above

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the safe level of 26 ppm) in a selected copper ore mine are mostly related to the blasting procedures. The time needed to reach a safe level of carbon monoxide concentration after a blasting procedure was also determined (with a given probability).

Moreover, the use of appropriate mathematical methods for data processing allowed the author to propose a variation model of hydrogen sulfide concentrations and to demonstrate a relationship between the level of hydrogen sulfide concentration and the ventilation process. Mining/technological processes have been shown to significantly affect the variability of the hydrogen sulfide concentrations, although this gas is from an exclusively natural source (the gas is released from the rock mass). This research has demonstrated that an intensive operation of ventilators causes excessive release of hydrogen sulfide from the rock mass, due to the resulting negative pressure.

Moreover, this dissertation also analyzes seismic signals. It proposes a new algorithm for the detection of P-waves (the so-called foreshadowing wave, crucial in identifying seismic hazards). The algorithm uses the time-frequency reprezentation of data and the PCA (Principal Component Analysis) method. The results were compared with the popular STA/LTA (Short-Term Average/Long-Term Average) method. The proposed algorithm gives more effective results.

The dissertation also discusses selected efficiency-related issues in the context of self-propelled underground machinery. It describes experiments which were conducted in order to confirm the possibility of evaluating the quality of the road and/or the driving style on the overall dynamic load of the machine, leading to accelerated wear. The study has also focused on an important problem of an automatic procedure for measuring production efficiency, i.e., measuring the number of machine (e.g., haul truck) cycles performed underground per shift. The author proposes to identify machine cycles by employing indicators alternative to the hydraulic oil pressure, which is the current standard, but which is subject to frequent failures.

This research has focused mainly on machine diagnostics. Nevertheless, other areas included in the investigations are an important part of the research hypothesis. Although each of the analyzed areas is described by different characteristics, the common denominator in the entire research was the application of advanced mathematical methods/processes to describe mining-related processes. The methods proposed in this study are intended to improve the effectiveness of mining operations, to increase workplace safety, and to optimize expenses related to machine operation.

Keywords: *local damage in machinery, gas hazards of underground mines, hydrogen sulfide, carbon monoxide, duty cycle detection, efficiency analysis of mining machines, seismic hazards, P-wave, time series, stochastic processes, signal processing, non-Gaussian noise, time-frequency analysis, dependency measures.*

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