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ABSTRACT
OF THE DOCTORAL DISSERTATION

Investigating structural and petrographic properties of coal in the aspect of methane hazard using methods of image analysis and artificial neural networks

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Investigating structural and petrographic properties of hard coal is extremely important in the light of the relationship between these properties and coal's technological and gas properties. Aside from the purely scientific aspect, such measurements play a key practical role in the industrial use of coal. The measurements are widely applied in the process of coal evaluation from the point of view of its use in the coking process. Such analyses are also carried out in collieries, to monitor the quality of the output, as well as to locate and identify contamination. Additionally, the authors of papers devoted to the issue of methane hazard in underground coal mines suggest that the internal structure of coal, which can be observed only under a microscope, may demonstrate certain features (such as the presence of cracks, cataclastic structures or mylonitic structures) that have an impact on the increased gas capacity and are helpful in identifying coal beds particularly threatened with gasogeodynamic phenomena.

Among the methods used to determine stereological parameters, the point analysis method and the linear analysis method are of the greatest importance. These measurements are typically carried out in a non-automatic way and are time-consuming, and thus troublesome for the researchers in charge of the analyses. When performing such measurements, a key issue is to recognize particular components of coal in a correct and repeatable way. Due to the huge diversification of coal's petrographic properties – a result of each component's different genesis – this task often poses a lot of difficulties, even to petrographers with long-time experience. The differences in the results of the analyses conducted by different petrographers are often considerable. Researchers point to the subjective factor as having a significant impact on such analyses, as well as to the need to make the investigations more objective.

The objective of the dissertation was to use artificial neural networks and methods of computer image analyses in order to develop an automatic, universal and repeatable methodology that would make it possible to identify, in microscope images, maceral groups and particular macerals of hard coal, as well as to classify structurally altered coal from near-fault zones. The aforementioned properties were classified solely on the basis of the knowledge obtained by the computer from sample microscope pictures and the information as to their content.

As part of the dissertation, the following research theses were formulated:

1. Identification of maceral groups and selected hard coal macerals in microscope images can be conducted with the use of artificial neural networks supported by the methods of automatic analysis of digital images.

2. Artificial neural network methods, combined with image processing methods, are useful in describing the structure of altered coal from near-fault zones, which is important from the point of view of outburst prevention in underground collieries.

3. Artificial neural networks may constitute a tool supporting microscope petrographic analyses of hard coal and verifying subjective decisions made by a researcher.

The Author believes that achieving positive results in her research may provide some conclusions that will be of interest to a wide range of receivers specializing in the issues connected with geology and mining, as well as in image processing and analysis and broadly understood artificial intelligence.

The dissertation presented here starts with introduction to the issues being tackled, as well as detailed discussion of the questions related to the petrographic-structural description of hard coal. The introduction contains a description of maceral groups and macerals of the inertinite group, the methodology of conducting analyses, as well as classification and characteristics of structurally altered coal from near-fault zones. Subsequently, a description of the image analysis and processing methods was provided, along with a description of artificial neural networks, as both these methods were used in classifying the analyzed petrographic and structural properties of coal.

Introduction to the practical part of the PhD dissertation and justification of the significance of the planned research were ensured by comparative manual analyses of maceral groups. The impact of the subjective factor in the process of conducting such measurements was analyzed, and the obtained results pointed to the need to look for new, automatic measurement systems based on AI methods.

In the chapters that follow, the Author proposed original algorithms of automatic classification of maceral groups, macerals from the inertinite group and altered structures of hard coal by means of selected neural classifiers (Multilayer Perceptron - *MLP*, Radial Basis Function network - *RBF* and Self-Organizing Map - *SOM*). For each of the discussed classification questions, the research material was thoroughly described, along with the selection of parameters describing the analyzed images, research into the choice of the optimal neural model, and comparison of the effectiveness of the applied neural networks in the classification of the studied objects.

The final stage of the research was to use the developed classification method in studies into the impact of the petrographic composition on selected sorption parameters of coal, which

directly influence the state of methane and outburst hazard in underground collieries. The analyses began with gravity separation in heavy liquids in order to single out, from one type of coal, samples of various densities and various petrographic composition. Subsequently, classification of maceral groups and non-organic matter was performed using the developed, automatic system of classification of investigated structures, based on AI methods. The obtained results were compared with selected sorption parameters of coal (sorption capacity – a_m and effective diffusion coefficient – D_e), and coefficients of correlation between them were calculated.

As a result of the conducted research, very high efficiency of the neural networks applied in the classification of the analyzed groups of objects was obtained. For each of the analyzed classification tasks, results exceeding 90% of correct identifications were obtained. This lets us presume that the proposed methodology (especially neural models taught in a supervised manner) may be successfully used as a tool supporting the decisions of an observer concerning the petrographic-structural description of hard coal. As this description is connected with the sorption properties of coal, the conducted research might also be a contribution to the complex analysis of the state of the methane and outburst hazard in hard coal mines.