mgr inż. Lucjan Świerczek

A new method of using the Graham's ratio to assess the fire hazard status in nitrogen inerted longwall areas

Abstract

The doctoral dissertation presents a new approach to assessing the fire hazard in the areas of longwalls inerted with nitrogen, because in mining practice situations often occur in which the additional concentration of nitrogen in air samples, taken for testing, causes difficulties in interpreting this hazard using the Graham's ratio. Therefore, one of the objectives of the dissertation was to formulate the rules for using this indicator to increase the credibility of the endogenous fire hazard assessment. An additional objective was to develop a universal method of assessing the fire hazard in all longwall regions – those not subjected to nitrogen inertisation and those subjected to this process.

To achieve the objectives, an analysis of Graham's ratio was carried out for the occurrence of unreliable cases. It has been shown that such cases result from the mathematical structure of the formula used to calculate the value of this indicator. Using the "Statistica" program, a credibility interval of Graham's ratio was developed, in which, at a probability level of at least 95%, it can be stated that this indicator correctly determines the state of fire hazard.

In the next part, the influence of the increased nitrogen content in air samples, taken for testing, on the value of Graham's ratio was examined. The results of these studies showed that in mining areas where nitrogen is used for inertisation, the value of Graham's ratio may be underestimated compared to the actual level of fire risk – despite meeting the credibility criterion of this indicator. It turned out that the given credibility interval may be insufficient in the case of air samples taken from places where nitrogen is used as an inert gas. Therefore, an additional criterion for Graham's ratio was developed, which should be taken into account in the case of air samples containing nitrogen in the amount greater than or equal to 80% and for which the discussed indicator classifies such a case as a normal situation ($0 < G \leq 0.0025$), i.e. no risk of endogenous fire.

The next part of the dissertation presents a solution to the problem of unreliable and negative values of Graham's ratio using artificial neural networks. For this purpose, an analysis of 24 multilayer perceptron topologies was carried out, which differed in the number of hidden layers and the number of neurons in each layer. The developed networks were trained using data from precise chromatographic analyzes of mine air samples, and then their goodness of fit to the test data was analyzed.

When comparing the fire hazard levels determined using the Graham's ratio and the selected artificial neural network, it was found that the network was resistant to disturbances associated with elevated concentrations of nitrogen and/or methane in the air sample. Also the presence of air samples containing high oxygen concentrations, which is a common occurrence in mining practice, did not significantly affect the predictive ability of the network.

It therefore turned out that the developed method of fire hazard prediction using an artificial neural network is very versatile and can be used to assess the state of danger for longwall regions that are not subject to nitrogen inertisation and for those that are subjected to this process. However, in cases where Graham's ratio exceeds the credibility range or assumes negative values, it can be a reliable indicator of the actual state of the threat.

The conclusions of the doctoral dissertation confirmed that the assumed objectives were achieved, which will result in a significant improvement in the reliability of determining the state of endogenous fire hazard, thus increase the safety of work in coal mines.