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The application of the GUHA method while searching dependencies of mine gas emission and barometric pressure changes

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Abstract

The process of firedamps´ release into worked-out areas, which often communicate with the surface after stopping the coal mining activity is very topical problem in the region of Ostrava. Firedamps contain namely dangerous methane, which is a result of the coalification process. Contemporary findings in this area show that the outflow of firedamps into the atmosphere is above all related to barometer pressure´s development. In 1995, the realization of degassing wells was initiated in region of Slezská Ostrava. Within the fremawork of monitoring, methane concentrations, gas-air mixture amount and barometer rates are measured among others. This paper gives information about mathematic data processing originated from the monitoring unit of the degassing well used for leading of firedamps from the underground, which is situated in Slezská Ostrava region.

Introduction

The history of coal mining in the region of Ostrava was more than 200 years long. The termination of coal mining was initiated in 1991, when a period of coal mining decrement and deep coal mines abolition started under authority of a decree of the government. After stopping the coal mining activity and after the technical abolition of coal mines, the process of firedamps' release into worked-out areas, which often communicate with the surface, is still going on. This happens mainly in areas where coal beds occur close to the surface. Methane is thus released from closed coal mines. This gas is dangerous mainly because of its explosiveness in mixture with air. Methane comes within so called greenhouse gases and so has a negative impact on global warming of Earth. In course of working of coal mines in Ostrava, the underground methane was lead off by ventilation and later by degassing. The firedamps' release intensity from worked-out areas is influenced by many factors, most significantly by barometer pressure changes [1, 2, 3, 4, 5, 6]. In 1995, the realization of degassing wells was initiated. Its goal was to prevent the area from uncontrolled gas release. Searching and of old major workings and its equipment by exhaust gas raises started to be carried out as well.

An integral part of the created degassing system is an implementation of regular measurements in individual localities. Within the framework of monitoring, methane concentrations, gas-air mixture amount and barometer pressure rates are measured among others. A part of these measurements was utilized for implementation of an analysis, the goal of which was to gain as much information as possible about relations within the measurements [7].

Data origin and exploitation goals

Analyzed data originate from the monitoring unit of the degassing well used for leading off damps from the underground, which is situated in Slezská Ostrava. Damps contain namely dangerous methane, which is a result of the coalification process. Its release is a natural process, which embodies a high rate of randomness. Contemporary findings in this area show that the outflow of firedamps into the atmosphere is virtually and above all related to barometer pressure's development. In case of lower rates of barometer pressure, firedamps are released from the underground to the

surface and it comes to their intermixture with the atmosphere. In case of higher barometer pressure rates, by contrast, the atmosphere is pushed back to the underground. Acquisition of knowledge is aimed right at this phenomenon's research [8].

The structure of gained data

The significance of attributes:

- *Date* – Date of the measurement. The measurement was realized from August 8, 2008, 7 AM to February 10, 2009, 6 AM every day in one hour intervals. The total amount of gained data was 4415;
- *Maximum_CH₄* – Real attribute with the significance of the maximum volume rate CH_4 in mixture in course of one hour of the measurement (%);
- *Average_CH₄* – Real attribute with the significance of an average volume rate CH_4 in mixture in course of one hour of the measurement (%);
- *CPM_UP* – Real attribute, the rates of which represent the amount of gas flowing to the atmosphere (m^3/h);
- *CPM_DOWN* – Real attribute, the rates of which represent the amount of gas returning to the underground (m^3/h);
- *Pressure* – Real attribute with the significance of barometer pressure at the time of the measurement (hPa).

Transformation and derivation of data

In terms of the following data preprocessing, we realized derivation of new attributes *CPM_DOWN--CPM_UP* and *LINE SLOPE_PRESSURE*. Their significance and motivation after the derivation will be stated below. Further the categorization of a number of attributes was carried out because of application of some methods to the analyzed data. It was not necessary to realize neither standardization nor normalization [9].

Derived attributes and their significance

- *CPM_DOWN-CPM_UP* – The difference of rates of attributes *CPM_DOWN* and *CPM_UP*. This operation can be carried out, because at the moment when one of the attributes has a non-zero rate, the other one certainly takes zero rate. The derived attribute thus records the air mixture flowage through the borehole – positive rates indicate flowing in the direction of the underground, whereas negative rates in the direction of the atmosphere. Instead of working with two attributes, we need only one now, which simplifies the following analysis.
- *CPM_DOWN-CPM_UP_CAT1* – Categorization of attribute *CPM_DOWN-CPM_UP* according to these intervals:

CPM_DOWN--CPM_UP	CPM_DOWN--CPM_UP_CAT1	Significance
(–, –20⟩	0	significant increase
⟨–20, –5⟩	1	increase
⟨–5, 5⟩	2	quiescent state
⟨5, 20⟩	3	decrease
⟨20, –⟩	4	significant decrease

- *CPM_DOWN-CPM_UP_CAT2* – Categorization of attribute *CPM_DOWN-CPM_UP* according to these intervals:

CPM_DOWN-CPM_UP	CPM_DOWN-CPM_UP_CAT2
(–, –5⟩	0
⟨–5, 5⟩	1
⟨5, –⟩	2

This double categorization of attribute *CPM_DOWN-CPM_UP* was carried out, because we were unable to estimate an optimal division into categories in advance.

- *PRESSURE_CAT* – Categorization of attribute *PRESSURE* according to these intervals:

Presure	Presure_CAT
⟨–, 999⟩	0
⟨1000, 1005⟩	1
⟨1005, 1010⟩	2
⟨1010, 1015⟩	3
⟨1015, 1020⟩	4
⟨1020, 1025⟩	5
⟨1025, 1030⟩	6
⟨1030, –⟩	7

- *LINE SLOPE_PRESSURE* – Real attribute, derived from attribute *PRESSURE*. This attribute was supposed to take into account, that the movement of firedamps is not only dependent on barometer pressure rate, but also on its time flow. In the graph (Fig. 1) we can see that in case of identical barometer pressure rates (blue indicators Nos. 1, 2), the rates of *CPM_DOWN--CPM_UP* (pink indicators Nos. 1, 2) differ significantly.

Therefore, we can suppose that the gases' movement through the degassing well is not only influenced by barometer pressure rate, but also by its development – i. e. whether it decreases or increases and how intensively. That is why we created a derived attribute *LINE SLOPE_PRESSURE*. Its rate for each measurement record (the point in the graph "Pressure development") is calculated as

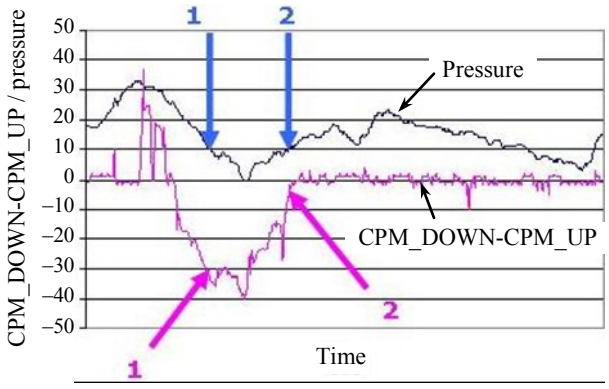

Fig. 1. CPM_DOWN-CPM_UP and pressure development

a line slope of a regression line [1], which we inset through the mentioned point and through ten previous ones. The figure 2 documents the calculation of attribute *LINE SLOPE_PRESSURE* for the 11th hour.

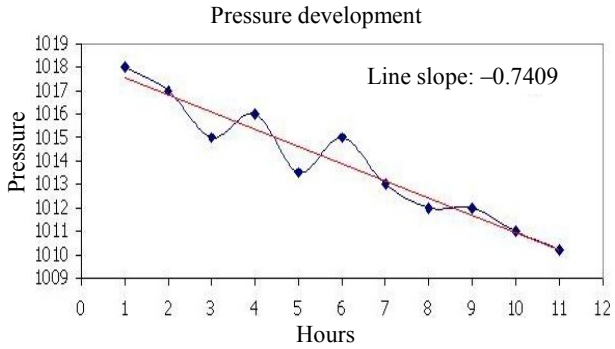

Fig. 2. Line slope calculation demonstration

According to the attribute's rate it is possible to state barometer pressure development:

- *LINE SLOPE_PRESSURE* > 0 … the pressure at the given moment increases,
- *LINE SLOPE_PRESSURE* < 0 … the pressure at the given moment decreases,
- *LINE SLOPE_PRESSURE* = 0 … balanced state,
- *LINE SLOPE_PRESSURE* ….... decrease / increase intensity.

LINE SLOPE_PRESSURE_CAT – Categorization of attribute *LINE SLOPE_PRESSURE* according to these intervals:

Line slope_Pressure	Line slope_Pressure cat	Significance
⟨–, –1.0⟩	0	intensive decrease
⟨–1.0, –0.3⟩	1	decrease
⟨0.3, 0.3⟩	2	balanced state
⟨0.3, 1.0⟩	3	increase
⟨1.0, –⟩	4	intensive decrease

- Categorization and attributes' derivation overview:

Original attribute(s)	Derived attribute	Operation
PRESSURE	*PRESSURE_CAT*	*categorization*
PRESSURE	*LINE SLOPE_PRESSURE*	*derivation by calculation*
LINE SLOPE_PRESSURE	*LINE SLOPE_PRESSURE_CAT*	*categorization*
CPM_DOWN--CPM_UP	*CPM_DOWN--CPM_UP*	*derivation by calculation*
CPM_DOWN--CPM_UP	*CPM_DOWN--CPM_UP_CAT1*	*categorization*
CPM_DOWN--CPM_UP	*CPM_DOWN--CPM_UP_CAT2*	*categorization*

Final structure of data

Attribute	Attribute type
Maximum_CH4	real
Average_CH4	real
PRESSURE	real
PRESSURE_CAT	categorical
LINE SLOPE_PRESSURE	real
LINE SLOPE_PRESSURE_CAT	categorical
CPM_DOWN-CPM_UP	real
CPM_DOWN-CPM_UP_CAT1	categorical
CPM_DOWN-CPM_UP_CAT2	categorical

Knowledge gaining

As already has been mentioned, the whole process of knowledge gaining will be focused on the research of barometer pressure's influence on firedamps' deportment. With regard to supposed existence of causal relation between attributes *PRESSURE* and *LINE SLOPE_PRESSURE* and attribute *CPM_DOWN-CPM_UP*, and with help of associations searching method GUHA [10], we realized these analyses:

PRESSURE and CPM_DOWN-CPM_UP relation

The following graph in the figure 3 shows the dependence of *CPM_DOWN-CPM_UP* rates only on attribute *PRESSURE*. In each interval of attribute *PRESSURE*, the column shows the setup of pertinence's probability into intervals of attribute *CPM_DOWN-CPM_UP*.

Generally, we can say that with increasing barometer pressure rates, also the probability increases that attribute *CPM_DOWN-CPM_UP* acquires positive rates and vice versa, which corresponds with the expectation. From the point view of security, we are naturally interested especially in intervals of attribute *CPM_DOWN-CPM_UP* ⟨–; –20⟩ and ⟨–20; –5⟩, when it comes to a significant exit of firedamps with CH_4 content to the surface.

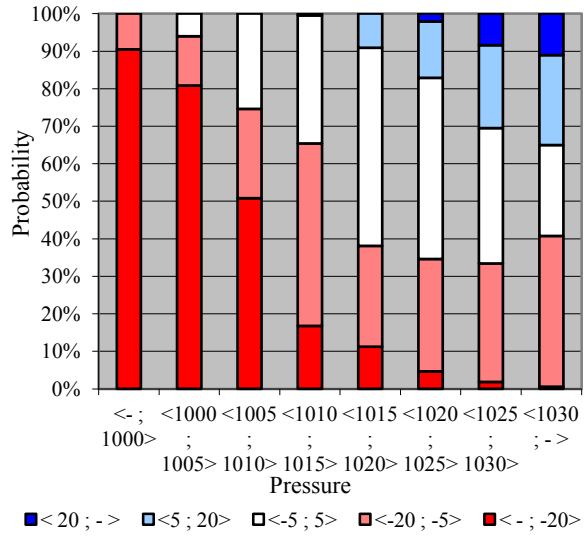

Fig. 3. Dependence of CPM_DOWN-CPM_UP on pressure rate

LINE SLOPE_PRESSURE and CPM_DOWN-CPM_UP relation

The following graph in the figure 4 shows the dependence of *CPM_DOWN-CPM_UP* rates only on attribute *LINE SLOPE_PRESSURE*. In each interval of attribute *LINE SLOPE_PRESSURE* the column shows the setup of pertinence's probability into intervals of attribute *CPM_DOWN-CPM_UP*.

From the graph we can find out that with increasing rates of the regression line's line slope, also the probability increases that attribute *CPM_DOWN-CPM_UP* acquires positive rates and vice versa. From the practical point of view it means that in case of increasing barometer pressure, the probability increases that the gas will be pressed down to the underground.

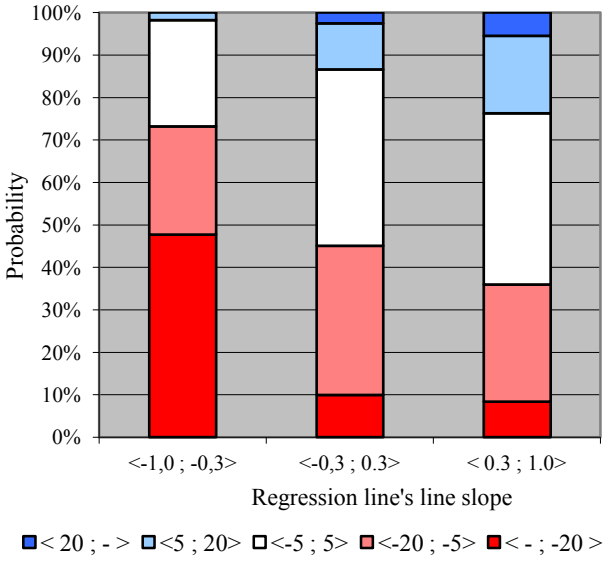

Fig. 4. Dependence of CPM_DOWN-CPM_UP on pressure development

Attributes PRESSURE and LINE SLOPE_PRESSURE and attribute CPM_DOWN-CPM_UP relation

When researching dependencies, we concentrated on searching of connection between barometer pressure and line slope expressing decreasing or increasing movement and the amount of firedamps getting out of the underground to the surface. Realized calculations have confirmed that in case of low barometer pressure, which was prefigured by its sudden decrease, the probability of firedamps' release into the atmosphere increases significantly. With increasing barometer pressure this probability decreases.

Analysis of the remaining attributes

From other, so far not analyzed attributes, especially *Average_CH4* attribute appears as interesting – real attribute with the significance of an average volume rate CH_4 in mixture in course of one hour of the measurement. To be able to describe its dynamics, it is necessary to characterize phenomena related to damps' movement.

Simply explained:

If barometer pressure is relatively high, the atmosphere is pressed into the underground and it "accumulates" in the surrounding of the degassing well's bottom (blue area in the figure 5a) and it simultaneously expands to the surrounding rocks.

At the beginning of barometer pressure decrease, it comes to an escape of damps to the surface. However, because an air with low CH_4 content is accumulated at the degassing well's bottom (blue area in the figure 5b), low rates of its content are measured by the monitoring unit. However, CH_4 content rates increase gradually and at the moment, when only an underground atmosphere is found at the degassing well's bottom area in the figure 5c), a gaseous mixture with relatively high and constant CH_4 content passes through the degassing well.

The time in which this CH_4 content increase lasts depends on the previous pressure development. If the period when the atmosphere is pressed down to the underground is relatively short, a small amount of atmosphere accumulates in the underground and at the moment of pressure decrease it comes to a very fast CH_4 content increase.

The graph in the figure 6 documents the above-mentioned observation.

In the graph we can see that at the moment of firedamps' exit to the surface (blue curve), an average CH_4 content in gaseous mixtre increases (red curve). We can also see that the increase rate and the maximum attained rate are dependent on the previous development.

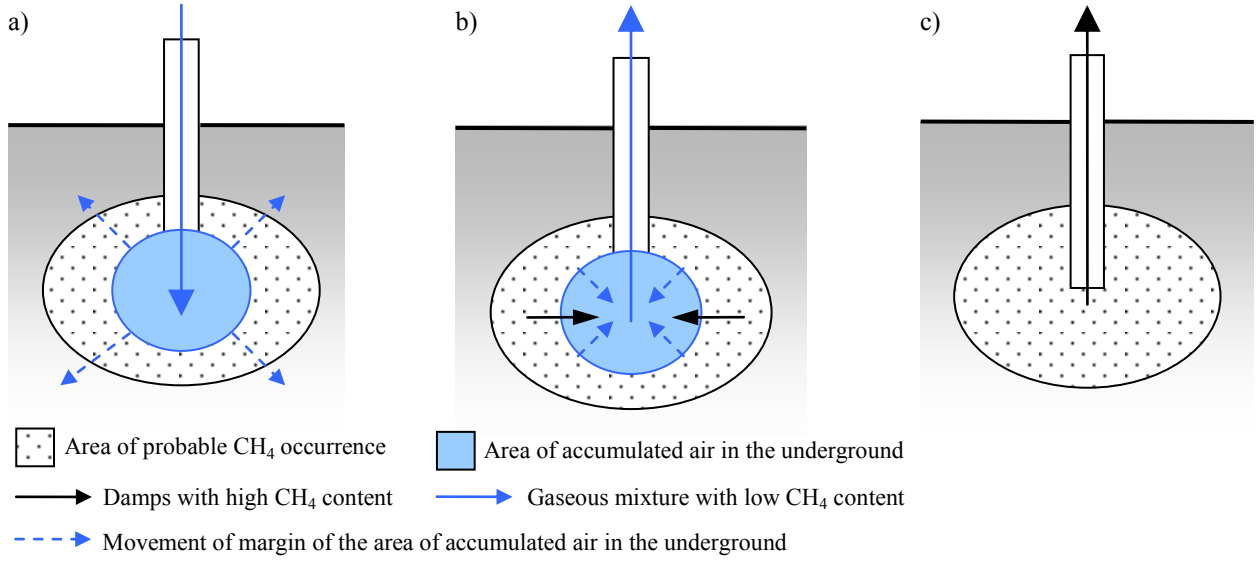

Fig. 5. Phenomena related to damps' movement

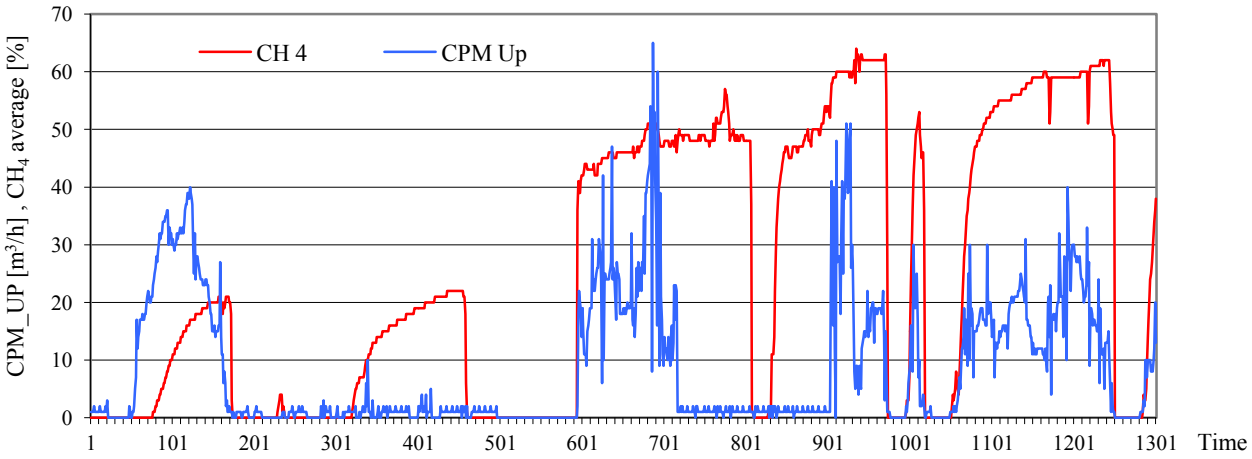

Fig. 6. CPM_UP and CH_4 average development

Conclusions

The construed pursuit concentrated mainly on studying the movement of gas-air mixture in the degassing well in dependence on barometer pressure development. Firedamps' release into the atmosphere is a natural process though, which embodies a high rate of randomness, but in use it was confirmed that it is influenced by barometer pressure's time flow. In case of its lower rates, firedamps are released from the underground to the surface. In case of higher pressure rates, by contrast, the atmosphere is pushed back to the underground. We tried to specify and express exactly the description of this relation by methods of acquisition of knowledge from data.

By GUHA method's application to analyzed data a hypothesis about the existence of causal relation between barometer pressure development and gases' movement in the degassing got well confirmed. The found rules made it possible to predict with a certain accuracy and on the basis of *PRESSURE* and *LINE SLOPE_PRESSURE* attributes' rates, what *CPM_DOWN-CPM_UP* attribute's rate will be (Figs 3, 4).

Average_CH4 attribute was not included into the analysis. For its analysis by methods of acquisition of knowledge from data, at first, it was necessary to derive several new attributes (taking previous *CPM_UP* development etc. into account). Anyway, the application of these methods would perhaps be difficult and apparently unsuitable for this type of data.

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