RESEARCHES REGARDING THE EVOLUTION OF THE COAL DEPOSITS IN "ROSIA DE JIU" QUARRY

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Abstract: To study the evolution of the temperature of the stock of coal depending on its storage period, the used method in managing the coal storages is the use of infrared thermography. Infrared thermography allows for the temperatures to be remotely measured (from centimetres to a hundreds of meters) and without direct contact, which is indispensable, for example considering electrical equipment found under tension or in the case of parts or materials with increased temperature or which are inaccessible.
The evolution of the measured temperature took into account the following steps: the initiation and appearance of temperature areas, the development phase of the temperature areas and the phase during which the increased temperature cores appear. The evolution of the temperature on steps is presented in data and in graphical mode. After the measurements the entire coal quantity which was analysed was sent to be consumed.

Key words: lignite, monitoring, self-heating, self-oxidation, temperature

Introduction

Coal oxidation represents an unwanted phenomenon which appears due to the interaction of coal with the atmospheric oxygen, phenomenon taking place during its life span, namely from the moment of its extraction until it is consumed. From an economic point of view, coal oxidation causes considerable losses in quantity as well as in quality at the production units as well as at the consumer ones, as the initial existent parameters were not found during its storage. In order to reduce this kind of phenomenon, it is required to follow the behaviour of coal, in time, stored in technological storages, to check the temperature of the stock periodically, to continuously monitor the zones liable to self-ignition, to methodically record all the factors involved in the oxidation of coal.

Self-oxidation and self-heating tendency

The oxidation phenomenon produces a series of changes of the natural properties of coal, such as:

- The reduction of the calorific power,
- The reduction of the burning properties,
- The substantial change of the surface of the granules,
- The change of carbonisation and pyrolysis properties.

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Considering the lignite extracted from "Roşia de Jiu" quarry, it hasn't still brought forward the problem of methodically following its behaviour in time (Krausz et al., 2003), given the fact that the period the coal is being kept on stock was, in most of the cases, relatively reduced, namely 30 days, therefore there was a small number of self-heating or self-igniting cases. A new orientation in is imposed concerning the preliminary production of coal on a monthly and yearly level, by programming the operation of excavators during the uncovering procedure with a proportion larger in relation to their operation during the extraction of coal. The purpose of this action is constituted by the insurance of a larger flexibility of production correlated to the oscillating demand of coal from the beneficiaries through a controlled storage which is comprised within the time limits in order not to affect the quality parameters of coal. It is necessary for the price calculation of coal to also distinctively foresee the additional expenses arisen with the management and conservation of coal stock-piles in own storage for a larger period of time, in order for the activity of the mines to profitable (Davidson, 1990; Huggins, 1989).

Rosia de Jiu coal reserve temperature monitoring

Roşia de Jiu quarry represents one of the main coal exploitations on the surface of Oltenia. Its production capacity exceeds 300,000 tons / month. The coal production is destined to the consumption of thermal power plants (30% for Rovinari thermal power plant to which the coal is hauled on conveyer belts and 70% destined for Turceni, Işalniţa, Craiova II and Arad thermal power plants, the coal being hauled in bulk in open hopper wagon). Considering that the storage place of the two piles, namely A and B, is relatively small (60,000 tons), one of the conditions for the realization of the production scheduled at the quarry is related to the period during which the coal is stored in piles. The small storage capacity of coal within the quarry is actually an advantage, because it implies a continuous dynamics of bringing in and removing coal from storage. Any coal immobilization for a period longer than 10 days leads to the obstruction of the excavation process and consequently to the cease of the activity of the quarry.

Measurement execution

In order to study the phenomenon of coal temperature increase from the interior of the stock of coal, it was required to delimit a portion of the storage (width = 35m, length = 35m, height = 10m, quantity = 10,437 tons), as not to disturb the coal layering and evacuation process from the rest of the storage. After having set the coal inside the storage, a number of 50 samples from 3 different areas were collected: namely, from the base, the middle and the superior area of the pile. After having analyzed the laboratory sample reported as initial state, resulted the data presented in Table 1. (*Oxygen was determined as a difference between 100 and $W_{î}^{i}$, W_{h}^{i}, A^{i} , S^{i} , C^{i} , N^{i} , H^{i} content.)

In order to study the evolution of the temperature of the stock of coal depending on its storage period, one of the methods most used around the world in managing the coal storages is the use of infrared thermography (Meola et al., 2004; Lizák and Kolcun, 2008). Infrared thermography allows for the temperatures to be remotely measured (from centimetres to a hundreds of meters) and without direct contact, which is indispensable, for example considering electrical equipment found under tension or in the case of parts or materials with increased temperature or which are inaccessible (Montelpare and Ricci, 2004; Shia et al., 2007; Sham et al., 2010). The measurements brought forward in the present paper (temperature monitoring) were made with the Medium Pro, Flir Systems T200 thermal imager.

Table 1. Data resulted after the analysis

No.	Specification	Value	Unit
0	1	2	3
1	Impregnation humidity [W_i]	40.46	%
2	Hygroscopic humidity [W_h]	3.94	%
3	Ashes content [A^i]	17.31	%
4	Sulphur [S^i]	1.14	%
5	Carbon [C^i]	29.98	%
6	Nitrogen [N^i]	0.52	%
7	Hydrogen [H]	2.12	%
8	Oxygen* [O^i]	4.52	%
9	Superior calorific power [Q_{sup}^i]	2346	Kcal/Kg
10	Inferior calorific power [Q_{inf}^i]	1974	Kcal/Kg

The evolution of the temperature is presented in Figure 1, distinguishing the following steps: the initiation and appearance of temperature areas, the development phase of the temperature areas and the phase during which the increased temperature cores appear.

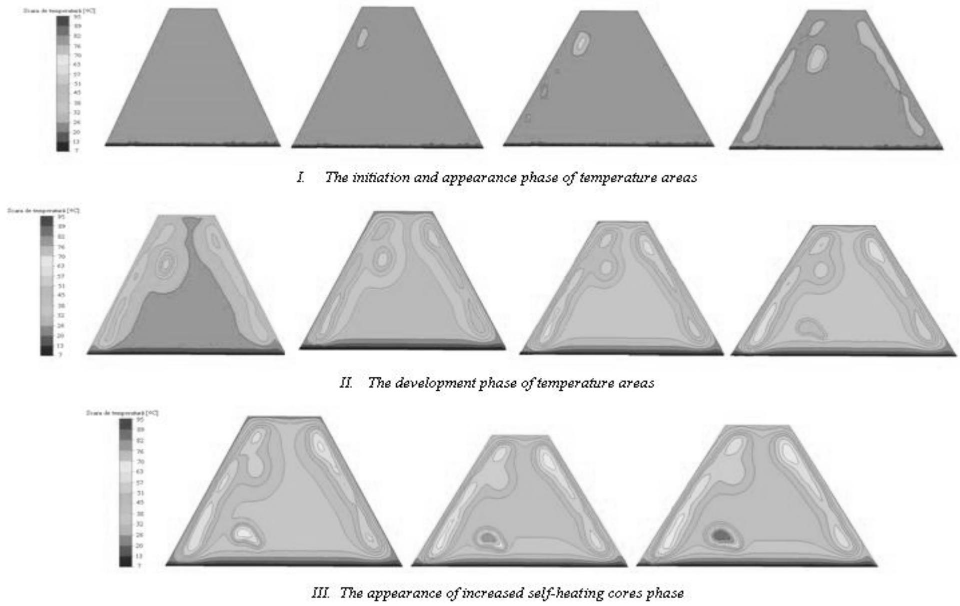

Figure 1. The evolution of the temperature on steps

The measurements were carried out every 5 days starting with the 1st of June 2013, distinguishing 3 phases.

The initiation and appearance of temperature areas phase

This phase is the characteristic of a 20 days period characterised by the appearance of areas with a more increased temperature than the rest of the pile, found a depth of 0.70m from the sides of the eastern and western talus. The phenomenon is due to the turbionary circulation of air on the line of separation of granulometric classes, ascending from the base towards the superior part of the coal pile. The temperature increase is more prominent on the eastern talus than on the western one, due to a larger granulometry of coal and the action of environmental factors (sun, wind, humidity, etc.) as the storage period increases, the temperature cores unite as continuous belts leaving from the superior part of the pile towards its base (Dobra et al., 2013).
The maximum temperature for this period is 38°C located in the superior part of the pile of coal, which appears as an elongated loop.

Temperature area development phase

Compared to the first phase of the oxidation – self-heating process of coal, this phase manifests through an increase of temperature at an increased intensity, also observed through the extent of the more increased temperature areas in the interior of the pile as well from 26 to la 38^{0}C. The pre-existing areas with temperature enhance their area in the following 40 days from their piling as to even reach 63^{0}C in certain spots.
At the end of the 40 days period the collection and sampling of the pile operation was repeated resulting in a decrease of the organic components in the detriment of inorganic composition (Table 2), *Oxygen was determined as a difference between 100 and $W_î^i$, W_h^i, A^i , S^i , C^i , N^i , H^i content.

Table 2. Data resulted after the analysis

No.	Specification	Value	Unit
0	1	2	3
1	Impregnation humidity [$W_î^i$]	39.04	%
2	Hygroscopic humidity [W_h^i]	3.94	%
3	Ashes content [A^i]	20.19	%
4	Sulphur [S^i]	1.03	%
5	Carbon [C^i]	28.55	%
6	Nitrogen [N^i]	0.69	%
7	Hydrogen [H^i]	2.76	%
8	Oxygen* [O^i]	4.48	%
9	Superior calorific power [Q]	2309	Kcal/Kg
10	Inferior calorific power [Q]	1916	Kcal/Kg

Generally, the temperature increase leads to the decrease of the humidity of coal, the increase of ashes content and consequently the decrease of calorific power with 58 Kcal/Kg, while the S^i , N^i , H^i content represent a reduced variation.

The appearance of increased self-heating cores phase

The last 15 days are characterised by the appearance and development of a core with a temperature over 76^0C situated on the eastern side of the pile of coal at a height of approximately ¼ from the base. The phenomenon is characterised by the appearance of vapours at the surface of the pile during the entire day and the change in colour of the coal following the endothermic and exothermic reactions within the coal pile. Graphically materialising the evolution of temperature during the analysed period (55 days) it is observed that the form of the tendency linear equation is: $y = 1.176x + 13.34$, while the square average deviation is: $R^2 = 0.977$ (Figure 2).

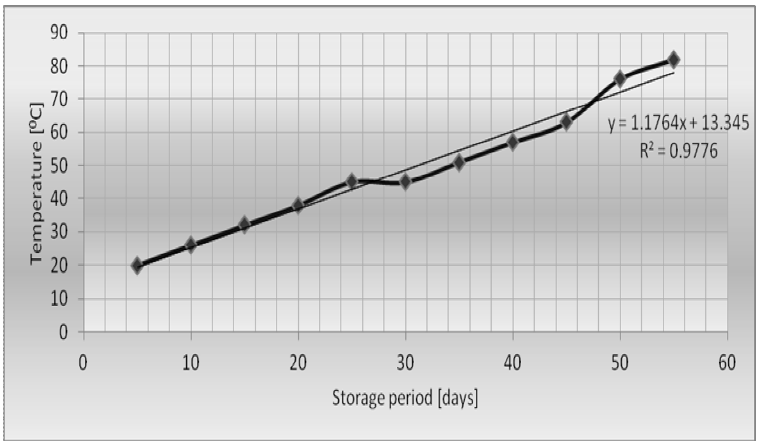

Figure 2. Evolution of temperature within the piles according to the period of storage of coal

Conclusions

- Quality depreciation is due to the oxidation phenomenon which is manifested by the interaction of coal grains with the atmospheric oxygen under the action of environmental factors;
- The self-heating cores appear on the separation line between coarse-grained coal and fine-grained one;
- The self-heating process of coal is more intense of the eastern side of the talus than on the western one;
- After 40 days from having piled the coal, its humidity decreases by 4.51%, the ashes content increases with 16.63 while the calorific power decreases with 58 Kcal/Kg;

– According to the graphical representation of the evolution of the temperature depending on the storage period it is observed the existence of 3 temperature thresholds:
  • 1st threshold, characterised by a constant linear increase of temperature within the range 20÷40^{0}C during 30 days;
  • 2nd threshold, characterised by the increase of temperature within the range 40÷63^{0}C in 15 days;
  • 3rd threshold, characterised by an accentuated increase of temperature, namely in 10 days from 63 to 82^{0}C.
– After having recorded the temperature of 82^{0}C, measures to locate and remove the area with increased temperature (over 82^{0}C) where undertaken and the entire coal quantity which was analysed was sent to be consumed.

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BADANIA DOTYCZĄCE EWOLUCJI ZŁÓŻ WĘGLA W KOPALNI "ROSIA DE JIU"

Streszczenie: Do badania rozwoju temperatury zapasów węgla w zależności od ich okresu składowania, stosowaną metodą zarządzania magazynami węgla jest termografia podczerwieni. Termografia podczerwieni umożliwia zdalne mierzenie temperatury (od centymetrów do setek metrów) oraz bez bezpośredniego kontaktu, który jest niezbędny, na

przykład biorąc pod uwagę urządzenia elektryczne pod napięciem lub w przypadku części lub materiałów o podwyższonej temperaturze lub które są niedostępne.
Ewolucja zmierzonej temperatury uwzględniła następujące kroki: inicjacji i wyglądu obszarów temperatury, fazy rozwoju obszarów temperatury i fazy, podczas której pojawiają się rdzenie zwiększonej temperatury. Rozwój temperatury w krokach przedstawiono w danych oraz w postaci graficznej. Po zakończeniu pomiarów całkowita ilość węgla, który analizowano została wysłana do konsumpcji.
Słowa kluczowe: węgiel brunatny, monitoring, samonagrzewanie, samoutlenianie, temperatura

研究演化煤礦地點"ROSIA DE JIU"

摘要：研究根据他们的储存期的煤炭储量温度的开发，仓储管理方法所用的碳红外热。红外热能使温度（从几厘米到几百米），并没有直接接触，这是必要的，例如远程测量，给出电电压或任何部件或材料在升高的温度，或者是不可用的。
测得的温度的演化包括以下步骤：开始温度和外观的区域，发展阶段和相温度区，那里有核心温度升高。在数据和以图表形式示出的步骤中的温度的发展。后测定碳的分析被送往用于消费的总金额。
關鍵詞：褐煤，監控，自加熱，自氧化，溫度