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CRITICISM OF PREDICTION OF COAL SELF-IGNITION

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ABSTRACT
Regarding difficulty of theoretical clarification of coal self-ignition, from purely practical reasons, particularly economic and ecological ones, interest has been focused on prediction of tendency of coal to self-ignition. A test should be available for this purpose which would enable, based on testing a small sample of coal extracted from a seam or collected from a coal store, using an easy technique, to generalize self-ignition ability of the whole coal contained in systems given. At the choice of method expected to describe this process with a single, preferably simple mechanism, direct oxidation of coal with a gaseous medium, either pure oxygen or air oxygen, was preferred. In this case, two tests are most often referred to, Olpinski´s method and adiabatic method, which also need to be critically assessed, since the self-ignition of coal should be considered as a uncertain phenomenon which in its complex nature cannot be unambiguously determined in time and space.

KEYWORDS: coal self-ignition; methods of prediction; sense of laboratory test

1. INTRODUCTION

Self-ignition of coal is of a great importance, and there are two aspects to pay attention to it: a) a scientific aspect, i.e., clarification of principle of the process denoted as self-ignition, of mechanism of the processes bringing about coal ignition as a final stage of the whole process, and definition of conditions required to its induction and realization, b) a practical aspect of a dangerous natural phenomenon, namely regarding safety of mining and provision of following protection of the coal extracted from mines at further manipulation.

Since half of the last century when a whole range of sciences (geology, chemistry, physics, mining) with their exact methods were involved into the problems of self-ignition, coal self-ignition has become an object of aimed study. Several theories have been worked out, however, none of them has been able to explain completely the mechanism of spontaneous increase of coal temperature up to its ignition. Although under artificial conditions, e.g. in laboratory, maximum of parameters are simulated which, according to empirical knowledge, accompany the temperature increase, always there are conditions created artificially for a forced temperature increase instead of a spontaneous increase of coal temperature up to the ignition point. Experimentally obtained results characterize then a certain process finished usually far below the point of coal ignition and claimed to pass to self-ignition under certain favorable circumstances. Yet, it has not been explained what are these certain circumstances about, and how this proceeds.

2. CONTINUOUS OXIDATION OF COAL

Among the theories proposed, continuous oxidation of coal within a broad range of temperature has become a preferred one. It is based on a simple consideration that if combustion is oxidation, then virtually the whole process of self-ignition is a continuous oxidation reaction starting already at low temperatures, following a whole range of temperature increase, and terminated at the point of ignition. However, recently it has been suggested (Medek and Weishauptová, 1999), that coal oxidation at various temperatures below the point of its ignition is accompanied by formation of chemisorption complexes decreasing significantly oxireactivity_of the coal surface at its following interaction with oxygen. This chemisorption proceeds very rapidly with its rate increasing with temperature. At the temperatures around the ignition point, a shock contact of the coal surface with oxygen resulted in its immediate inactivation, so that ignition did not occur whereas an increase of the original ignition point.

Since this simple mechanism of spontaneously proceeding oxidation has not yet been proved experimentally despite numerous trials, several authors have concluded that an initiation factor is required which would supply the system with a necessary activation energy in form of a strongly exothermic reaction. Character and effect of such a factor, however, has not been neither theoretically sustained nor in situ proved. A sufficient proof of necessity of this initiation exothermic reaction is here the historic experience of a fireplace filled with coal which, according to some not quite clear criteria, should strongly tend to self-ignition, and still it would be quite absurd to expect its spontaneous ignition. Although it cannot be excluded theoretically, always for the present it has been necessary to set it on fire, and thus supply the system with a sufficiently high energy directly inducing the final oxidation reaction in form of a local ignition.

From the principle of a continuous oxidation reaction which is a basis for the laboratory tests presented below, also an answer is intuitively derived to all the questions connected with the principle of the process of self-ignition. Although individual modifications of this method in the frame of laboratory tests enable to know more about the reaction of oxygen with coal matter under various artificially induced external conditions, these are however mostly far from a natural situation. The worst disturbance of reality is supplying heat into the system from outside, while at the real self-ignition, on the contrary, heat is generated by the system. That is why results of such tests should be considered only as determination of certain parameters of the interaction of coal with oxygen expressed as, e.g., oxireactivity (Taraba, 2003), barely as a tendency of coal to self-ignition.

3. METHODS OF PREDICTION OF COAL SELF-IGNITION

Regarding difficulty of clarification of self-ignition based on theoretical research, from purely practical reasons, particularly economic and ecological ones, interest has focused on prediction of tendency of coal to self-ignition. A test should be available for this purpose which would enable, based on testing a small sample of coal extracted from a seam or collected from a coal store, using an easy technique, to generalize self-ignition ability of the coal contained in systems given. At the choice of a method expected to describe this process with a single, preferably simple mechanism, direct oxidation of coal with a gaseous medium, either pure oxygen or air oxygen, was preferred. In this case, two tests are most often referred to, which also need to be critically assessed.

3.1. OLPINSKI´S METHOD

So far quite widely used, the Olpiňski´s method (Olpiňski, 1959) results in air media in so called self-ignition index SZ^b related to ash-free base. This index with the dimension [^oC/min], with its value usually about 100, is obtained as a derivative of the dependence of increasing temperature T [^oC] of a coal briquette on time τ [min] at T = 232 °C corresponding to the boiling point of quinoline. If the resulting value $SZ^b < 100$ then according to Olpiňski coal does not tend to self-ignite, at $SZ^b > 100$ it does. As this index by itself does not always correspond to observed self-ignition, Olpiňski introduces also several empirical factors affecting the process under in situ conditions. There are altogether 50 factors characterizing mine and mining conditions with values ranging from +15 to –15 and, according to Olpiňski, with the same unit as the SZ^b index, or a relative index common for all the quantities considered is introduced. By their addition SZ^b is corrected to so called complex index PS, which can significantly differ from the basic SZ^b in both directions.

However, this method is hindered by a parameter casting doubt on its applicability. It is the temperature of 232 °C at which the "self-ignition" index is determined, since the point of ignition can be already found for coal around this temperature. The temperature, neither physically nor chemically justified, is reached in coal by a very quick contact with a screen heated by vapors of boiling quinoline, so that an internal process of spontaneous temperature increase cannot be considered at all. At the given temperature, probably rate of a strongly exothermic process is determined, i.e., of ignition or already burning, as indicated also by a steep increase of recorded temperature with time around this temperature point. Thus, the SZ^b index alone has no sense for determination of tendency of coal to self-ignition.

On the other hand, an advantage is introduction of mining factors based on practical experience, which participate at the genesis of endogenous fires. Their significance and a related grading is certainly individual for each coalfield, however, in a whole they can by themselves represent an empirical criterion to judge a dangerous situation.

3.2. ADIABATIC METHOD

Another test is based on so called adiabatic method existing in various modifications. Usually, pure oxygen flows through a coal layer, and each temperature change in coal is accompanied by equal, artificially induced temperature change of its surrounding, so that a mutual heat exchange is prevented. This way, the necessary condition of thermal isolation in situ should be simulated, and at the same time justified the assumption of a minimal, so called "critical volume", which should fulfill the condition given. This assumption is interdicted by the adiabatic method since the exothermic oxidation reaction takes place on surface, and depending on heat conductivity of coal, a portion of the heat produced is transferred following temperature gradient into the coal bulk losing thus its original amount. Two conclusions follow from this fact.

First, it is the term of "critical volume" whose meaning is most relative, since the greater the coal volume, the greater loss of the surface temperature in a given time interval. For a minimum loss of the heat produced on the surface, contrariwise a very small sized grain would be ideal where heat conduction in the direction from the surface would be suspended by heat flowing from surrounding surface sources. This process can be roughly realized at a laboratory test, but it does not correspond to in situ conditions, where in coal formations of a significantly larger size the absorbed heat can reach limit values. At the laboratory test, the "critical volume" is substituted by a larger layer of small-grained coal which individual dimensions are in a certain size range. According to actual temperature picked up mostly at a certain spot of the layer, compensation temperature of the surrounding medium is controlled. It is not guaranteed that the whole layer has the same temperature as that picked up at the spot, so that heat transfer between the layer and medium in both directions cannot be precluded. Thus the principle of adiabatic process is broken and in each point stimulated this way, coal is being brought to an equilibrium thermal state which does not belong it in the frame of expected continuous oxidation.

In authors' earlier studies a system has been chosen where temperature of surrounding medium was continuously set to 1 – 2 K lower value compared with the registered coal temperature, and this way a spontaneous and by thermally not affected increase of temperature was provided.

4. LOGIC OF THE PROBLEM

Besides objections from the reaction standpoint, crucial doubt about predicating ability of the tests on coal tendency to self-ignition are in the extent of their following realization. In order that a test is effective, one must presume that coal properties are equal in the system given in a certain section of seam or wall or in a certain volume of pile (e.g., extracted or stocked coal). On condition that also external conditions (temperature, heat transfer, composition of gaseous medium, its pressure and humidity) are equal in the system considered, the tendency to self-ignition should show equally anywhere within the coal complex considered.

If for example in the vicinity of site *A* a coal sample was taken which was proved by test No.1 to tend strongly to self-ignition, then with all the external conditions fulfilled ignition of the whole coal complex would have to occur (if it ever occurred), as each site should have the same favorable conditions for it. The main claim, however, should be on side of the site *A* coal, since namely for it all the conditions for self-ignition were found. Nevertheless, it can happen that coal ignites not in site *A* but in a more distant site *B*, possibly as the only one in the whole coal complex. Why in the site *B* and not in site *A*? When in an additional test No. 2 coal from not affected vicinity of site *B* is analyzed showing that coal in the vicinity of *B* has roughly equal tendency to self-ignite as at site *A*, then the active site *B* should characterize also activity of site *A* where, however, contrary to the test No. 1 ignition did not occur. Hence, some difference has to exist between both sites in time and space which the testing methods are not able to register. Let us consider that in agreement with the analysis ignition of coal in site *A* follows. A question emerges, why the coal did not ignite before or even during sampling but after only certain time, when it had given beforehand a disposition for it.

5. PRACTICAL MEASURES

A test result indicating that coal in a sample collected tends, even strongly, to self-ignition should lead to practical measures. However, it cannot be expected in case of a positive result of the test without ignition of coal in situ, that pile is dismantled, gallery back filled up and the suspected wall covered with a gas-proof isolation layer. Regardless of positive or negative result of the test, only in case of growth of a local endogenous fire well proved liquidation methods are applied. The smothering or burning coal is watered on band conveyer as well as transported briquettes, in case of increasing temperature or igniting in a seam or wall (if the site is accessible) the hotbed is liquidated by digging out or it is quenched with nitrogen, a dump with smothering coal is rolled down or scattered.

6. CONCLUSION

Since the self-ignition of coal should be considered as a uncertain phenomenon which in its complex nature cannot be unambiguously determined in time and space, from standpoint of recognition only clarification of its causes and mechanism makes sense. Although their nature cannot be directly described, yet it is possible to formulate theoretical assumptions which would correspond to coal character and properties and at same time meet the observed phenomenon from the physical and chemical point of view. This is why the authors have recently worked out a new theory of the initiation of coal self-ignition (Medek and Weishauptová, 2003) based on a principle of spontaneous disconnection of coal by action of potential energy accumulated in coal matter and inducing mechanical stress. Consequence is formation of micro-cracks, while part of the potential energy dissipates into heat giving growth to micro-fires as primary seats of burning.

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