SPONTANEOUS COMBUSTION OF COAL AND ITS EARLY DETECTION IN OKR MINES

SAMOVZNÍCENÍ UHLÍ A JEHO VČASNÁ INDIKACE V DOLECH OKR

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Abstract

Occurrence of spontaneous combustion of coal in OKR (Ostrava-Karvina Coal Field) still represents current problems worthy of solution. In OKR mining operations it is necessary to minimize permanently a risk of endogenous fire and its consequences to which as well a potential risk of possible initiation of air-methane mixture belongs that could lead to serious consequences in the form of mine accident accompanied by losses of human lives. The valid mining legislation of the Czech Mining Office imposes to check carbon monoxide occurrence in the mine atmosphere. Tracking further indicator gases of spontaneous combustion is imposed in the OKR mines by Decision of the District Mining Office in Ostrava [1]. The aim of the decision is to minimize risks resulting from occurrence of spontaneous combustion in the OKR mines. Actual findings confirm importance of inspection of indicator gas occurrence in the mine atmosphere as well as complexity of temperature estimation of the centre of spontaneous combustion. The presented paper deals with spontaneous combustion process, occurrence of spontaneous combustion of coal in OKR mines, some findings in the area of early detection of coal by indicator gases, it gives reasons for actual reserves in the given area and consider possibilities of improvement of temperature estimation of spontaneous combustion.

Abstrakt

Výskat samovznícení uhlí v OKR je stále aktuální problematikou zasluhující řešení. V důlních provozech OKR je nutno trvale minimalizovat riziko endogenních požárů a jejich následků, mezi které patří rovněž potenciální riziko možné iniciace metanovzdušné směsi, která může mít vážné následky v podobě důlní havárie doprovázené ztrátami na lidských životech. Platná báňská legislativa Českého báňského úřadu ukládá kontrolu výskytu oxidu uhelnatého v důlním ovzduší. Sledování dalších indikačních plynů samovznícení ukládá v dolech OKR rozhodnutí OBÚ v Ostravě [1]. Cílem tohoto rozhodnutí je minimalizovat rizika vyplývající z výskytu samovznícení v dolech OKR. Dosavadní poznatky potvrzují závažnost kontroly výskytu indikačních plynů v důlním ovzduší a rovněž potvrzují složitost odhadu teploty ohniska samovznícení. Předložený článek se zabývá samovzněcovacím procesem, výskytem samovznícení uhlí v dolech OKR, některými poznatky v oblasti včasné indikace uhlí pomocí indikačních plynů, zdůvodňuje dosavadní rezervy v dané oblasti a zamýšlí se nad možnostmi zdokonalení odhadu teploty samovznícení.

Key words : early detection, spontaneous combustion, spontaneous heating, thermal oxidation, carbon monoxide, carbon dioxide, higher hydrocarbons.

1 INTRODUCTION

Ones of the first scientific findings on spontaneous combustion of coal originate from the first half of the twentieth century from Great Britain, where renowned authors Winmill, Graham, Coward and others worked in research laboratories of private mines. The objective findings in the area of spontaneous combustion concerned especially oxidation of coal mass, kinetics of spontaneous combustion and indicator gases, e.g. till now known and respected Graham's ratios [2,3]. Further noticeable progress in early detection of spontaneous combustion was made by Japanese and Evropean research in the area of tracking higher hydrocarbons, e.g. [4-9]. The Czech parts takes hold in the seventies in the Mining Research Institute of the Academy of Sciences of CR, in the Science-Research Coal Institute in Ostrava-Radvanice [11] and in the eighties also at the Central Mines Rescue Station in Ostrava [12]. The above-cited research in CR brought a series of findings in the area of temperature estimation of the centre of spontaneous combustion and provided backgrounds for adoption of the above-mentioned Decision of the District Mining Office in Ostrava [1].

A later research in the given area was realized in CR within research and development activities of the Czech Mining Office and was focused on improving methods of early detection of spontaneous combustion [13, 14]. The research started from actual findings and extended knowledge in the area of kinetics of spontaneous combustion of coal in OKR, repeatability of thermal oxidation method, factors affecting temperature estimation accuracy of spontaneous combustion, application of computer technology when estimating temperature of spontaneous combustion.

2 SPONTANEOUS COMBUSTION OF COAL AND ITS OCCURENCE IN OKR

Susceptibility of coal mass to spontaneous combustion is conditioned by carbonization degree within the range from lignite to anthracites. In case of deep lignite mining spontaneous combustion does not usually manifest itself under mine conditions namely by reason of high water content. High susceptibility to spontaneous combustion becomes evident in lignite coals and in many cases susceptibility to spontaneous combustion reveals itself also in less carbonized black coals. Spontaneous combustion of more carbonized black types of coal and anthracites occurs quite as an exception. One can say that the risk of spontaneous combustion in mining operations is given by three following factors:

- chemical-physical properties of coal,
- natural conditions of coal mining,
- technical conditions of coal mining.

Dynamics of spontaneous combustion process has an exponential behaviour. It is characterized by developing incubation stage up to reaching a critical temperature whose mean value for the OKR coal is according to [16] 83°C. Then development of spontaneous combustion process occurs in cases of non-damped centres up to achievement of ignition temperature of coal. A specific period of time of individual stages is affected by a series of factors and depends among others also on susceptibility to spontaneous combustion of coal. Mutual ratio of time of incubation stage to stage developed in OKR is at average 5:1[15]. It means that if we take into account in practice-verified incubation period of spontaneous combustion six weeks (which includes as a rule also the stage developed), the temperature rise of the centre of spontaneous combustion from the rock temperature to achievement of the critical temperature lasts five weeks and after exceeding the critical temperature the rise to the ignition point for non-damped spontaneous heating lasts only one week. The factor underlines a key significance (if possible) of precise estimation of critical temperature of spontaneous combustion in practice.

Spontaneous combustion of coal mass is a serious and still actual risk occurring in the Karvina part of Ostrava-Karvina Coalfield. In OKR at an average 20 cases is reported of a limit occurrence of carbon monoxide. Hereby several incidences per year by their extent go over to extensive endogenous fire [17]. Total 273 cases of a limit occurrence of carbon monoxide was reported in OKR in the years 1993 - 2006. Thereby 212 (77%) cases occurred in coalfaces. A criterion for recording is according to the Decision of District Mining Office in Ostrava no. 10/1990, article 05, i.e. CO concentrations higher than 0.003 % or volume formation of CO of 10 l/min and higher.

3 EARLY DETECTION OF SPONTANEOUS COMBUSTION IN OKR

A spontaneous combustion process is accompanied by an occurrence of indicator gases. The indicator gases split according to implemented routine of sampling mine atmosphere into major indicator gases (essential) - CO, CO_2, O_2 and minor indicators (additional) - H_2, ethane, propane, n-butane, i-butane, ethylene, propylene and acetylene. Sampling of air masses in the mine environment is regulated in the Czech Republic by the ČSN 83 0050 standard, i.e. taking wet samples by glass sample tubes (as usual of volume of 1 l) filled by sealing liquid and taking dry samples using vacuum ejectors.

Intensity of desorption of indicator gases from coal mass was tracked under the OKR conditions especially within catalogues of seams prone to spontaneous combustion liability, e.g. [18, 19]. Within the provided classification till the year 2002 in OKR total 64 coal samples were laboratory-verified (by thermal oxidation method) and classified, whose gas images became a base of a computer program database for temperature estimation of the centre of spontaneous combustion [20].

For temperature estimation methods of the Central Mines Rescue Station in Ostrava have been recommended in OKR since the eighties [12], that resulted from an interconnection of research results and operational findings. One of the methods has a graphic form, see Fig. 1. Temperature of a spontaneous combustion can be estimated by comparison of volume formation of indicator gases of the mine atmosphere with the presented column diagram. A disadvantage of the method is its application only to samples of the mine

atmosphere taken in through-circulating current with a known volume flow rate of the mine air. Indicator gases of spontaneous combustion occurs at first as a rule in a non-affected mine atmosphere, for instance in a gob of a coalfaces. In these cases it is advisable to use binary indicators for temperature estimation, i.e. ratios of indicator gases. Graham's ratios, till now obligatorily used in Polish mines [3], are inapplicable in the OKR coalfaces with inertisation by gaseous nitrogen with respect to oxygen decrease by effect of nitrogen injection. One of operationally usable binary indicators is the ratio of indicator gases CO_2/CO, see Fig. 2.

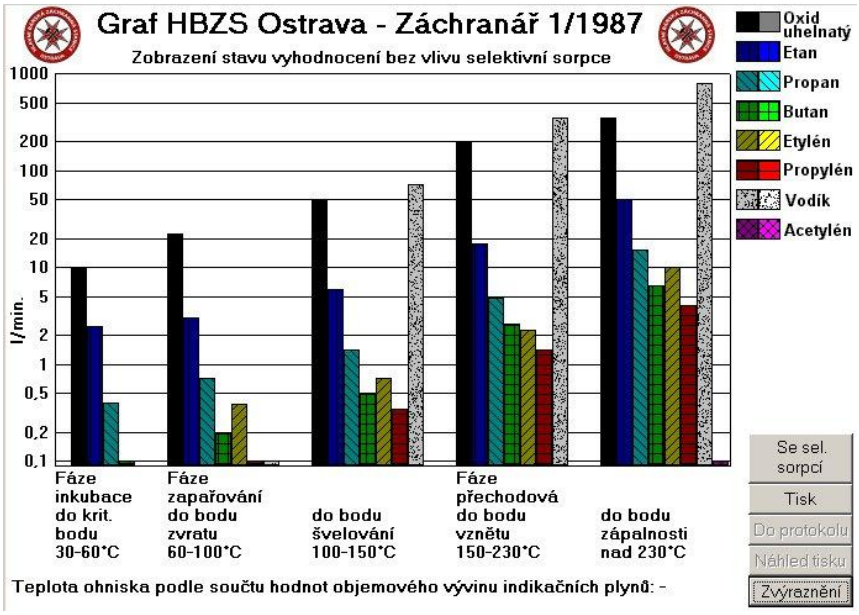

Fig. 1 Column diagram of the Central Mines Rescue Station Ostrava for temperature estimation of spontaneous combustion of the OKR coal [12]

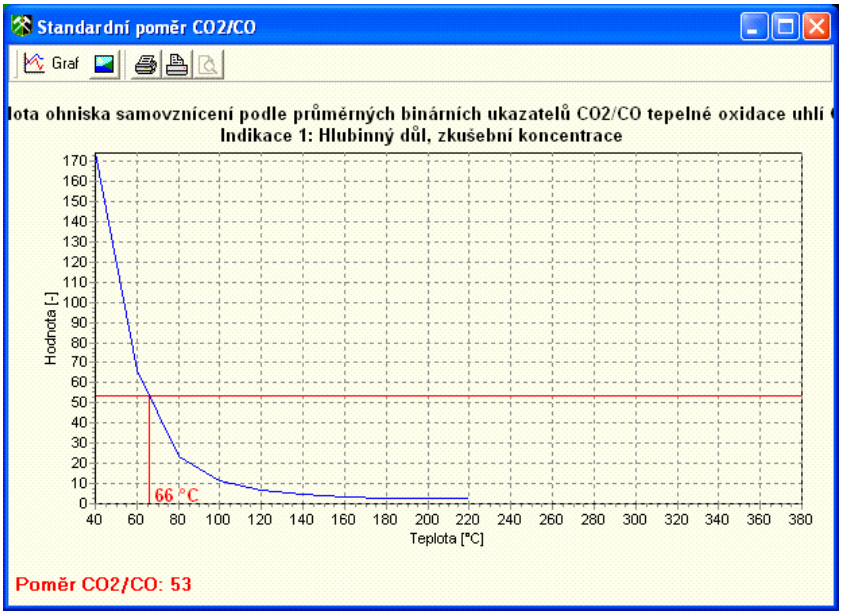

Fig. 2 Reference graph of the binary CO2/CO indicator of OKR [20]

Indication of temperature via CO_2/CO binary indicators can be used under relatively low temperatures (up to 100°C), however it is necessary to count with an underestimation of the estimated temperature to the actual temperature of spontaneous combustion. The underestimation consists in mixing of indicator gases desorbed from thermally non-homogeneous centre of spontaneous heating in the mine environment. In laboratory a desorption of indicator gases is in progress under standard conditions of the thermal oxidation method and based on these laboratory results an exponential reference behaviour of CO_2/CO binary indicator for the OKR coal was determined.

For estimation purposes of the temperature of the centre after exceeding the critical temperature of spontaneous combustion and while sampling the non-affected mine atmosphere the CnHm computing program can be used [20] allowing the assessment of any binary indicators through the use of the database of the indicator gases laboratory-acquired by the thermal oxidation method. One of such graphic assessment outputs is presented in Fig. 3.

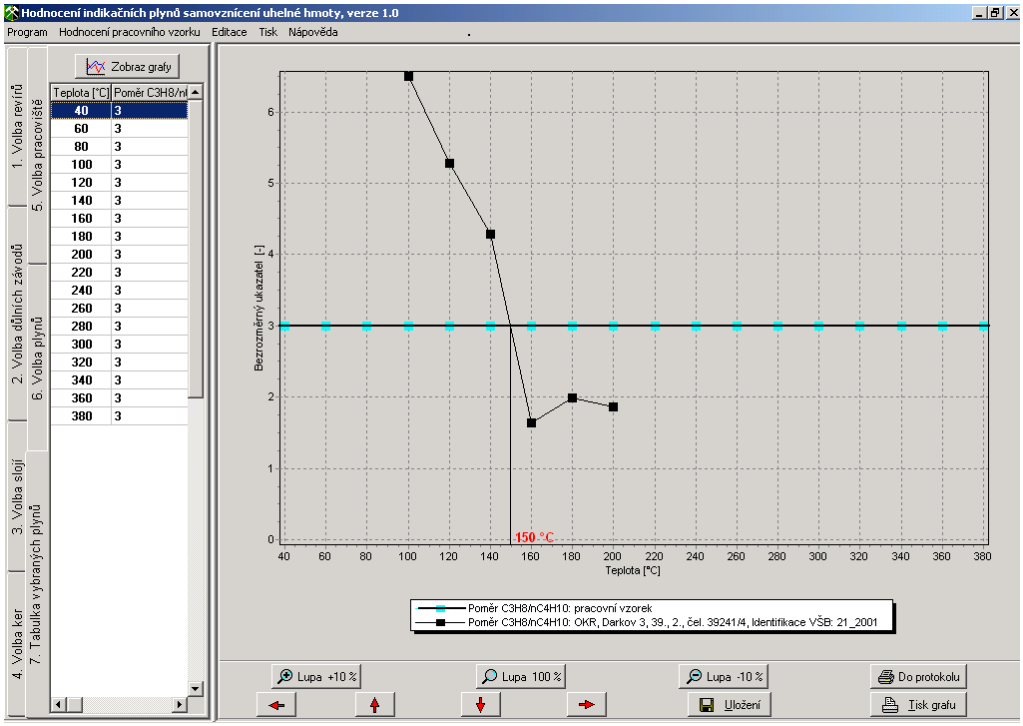

Fig. 3 Application of the C_3H_8/nC_4H_{10} binary indicator by the computer program [20]

From literature, e.g. [21] the recommended C_2H_6/C_3H_8, C_2H_6/C_2H_4 a C_2H_4/C_3H_6 binary indicators are known. However, the work with the "CnHm 2.3" computer program requires a detailed knowledge of problems of spontaneous combustion of coal in underground mines and operator experience.

4 CONCLUSIONS

Decision of the District Mining Office in Ostrava [1] imposes to track selected indicator gases of spontaneous combustion in the OKR underground mines. The mining legislation imposes to track and assess occurrence of carbon monoxide. In case of exceeding its concentrations of 0.001 % the Decision [1] imposes to track occurrence of higher saturated and unsaturated light gaseous hydrocarbons (with C2 – C4 carbon contents in a molecule). In case of repeatable occurrence of unsaturated hydrocarbons (C_2H_4,C_3H_6), when it is not possible to damp down the centre, the Decision [1] imposes to close the risk area. As well in case of occurrence of C_2H_2 it is necessary to close immediately the risk areas. Hereby a risk is minimised of a possible initiation of air-methane mixture because the unsaturated hydrocarbons indicate the temperature of a developed stage of spontaneous combustion and considering the above described dynamics of developed stage it is necessary after exceeding critical temperature of spontaneous combustion to consider the risk of initiation of air-methane mixture in gassy mines of the II class of hazard as actual.

Generally binding regulations of the mining legislation in CR have not dealt so far with estimation of temperature of spontaneous combustion of coal. In this area recommended procedures for temperature estimation are available to which the methodology of the Central Mines Rescue Station in Ostrava belongs for a non-affected mine atmosphere (assessment of absolute concentrations of indicator gases) and for through-circulating current (column diagram) [12]. For temperature estimation of spontaneous combustion as well the reference behaviour of the CO_2/CO binary indicator and the "CnHm 2.3" computing program can be used [20]. However, it is necessary to say in the context of temperature estimation through the use of the presented methods that accuracy of the presented methods is at the level of temperature estimation only, not at the level of temperature determination. Reasons can be seen in the wide desorption property of coal mass and in different laboratory

conditions in relation to conditions of occurrence of spontaneous combustion in practice [14]. The question is important for further possibilities of improvement of possible technological solution. Certain possibilities can be seen in increasing sensitivity of gas chromatography, which are offered today in connection with the technical development, or perhaps with verification of some foreign experience, e.g. the method being used in the Ukrainian mines, i.e. the use of the C_2H_4/C_2H_2 binary indicator at chromatography sensitivity of 10^{-8} (10^{-9}).

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RESUMÉ

Závažnost výskytu samovznícení v hlubinných dolech je stále aktuální a poutá pozornost hornické odborné veřejnosti. Riziko výskytu záparů v dolech souvisí především s ohrožením pracovníků v podzemí výskytem oxidu uhelnatého a s rizikem možné iniciace metanovzdušné směsi v plynujících dolech. Z provozních zkušeností plynujících dolů dobývajících sloje náchylné k samovznícení vyplynula potřeba řešení dané problematiky, která vyústila v řadu protizáparových opatření potlačujících a minimalizujících předmětná rizika.

V OKR jsou v daném směru aplikována závazná opatření založená na sledování celkem deseti indikačních plynů samovznícení, jejichž cílem je především ochrana důlních pracovníků před překračováním mezních koncentrací oxidu uhelnatého a zabránění iniciace metanovzdušné směsi teplotou ohniska samovznícení. Minimalizace rizika možné iniciace metanovzdušné směsi je zabezpečena uloženou povinností uzavřít ohroženou oblast v případech výskytů nenasycených plynných uhlovodíků za daných specifických podmínek. Pro účely splnění těchto požadavků jsou v OKR trvale provozovány monitorovací sítě oxidu uhelnatého, tři chromatografické plynové laboratoře a řada chemických plynových laboratoří.

Obecně závazná legislativa se dosud přímo nezabývá teplotou samovznícení. Pro tyto účely jsou v OKR používány doporučené metody, jejichž přesnost je na úrovni odhadu. Tento nedostatek by měl být předmětem řešení dané problematiky v budoucnosti .