VOL. 13, NO. 10, MAY 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ASSESSMENT OF THE INFLUENCE OF THE FIRST ESTABLISHED AND IDENTIFICATION OF CRITICAL STEPS IN MAIN ROOF CAVING

Oleg Ivanovich Kazanin, Andrey Alexandrovich Sidorenko and Evgenii Alexandrovich Vinogradov
Saint Petersburg Mining University, Saint-Petersburg Line, Russia
E-Mail: oleg.i.kazanin@mail.ru

ABSTRACT

The study is aimed at identifying the critical steps of main roof collapse when shallow coal seams are developed with long working faces. Factors have been noted that affect air flow formation during main roof collapse for the conditions of the Vorkuta Deposit in the Pechora coal basin of Russia. The most dangerous conditions have been determined, under which an emergency may occur in case of main roof collapse. A calculation scheme has been developed that takes into account the nature of the interaction between the immediate roof and the main roof. The need in the differentiated approach for the choice of efficient schemes of gas emission management for the protective seams and the main productive seams has been shown. Measures have been proposed for reducing the risk of gas concentration in the areas with hardly collapsible roofs. Conditions of excluding gas concentration in the gob excavations have been determined for the periods of main roof collapse in an established state.

Keywords: underground mining, coal seams, long wall, roof caving increment, main roof, roof caving, methane emission, numerical modeling.

INTRODUCTION

To assess the influence of the first and subsequent roof collapses on the state of protective structures and changes of the mine atmosphere in a working face and in adjacent workings, previous studies [3, 4] have been analyzed. It should be noted that observing the process of collapse and the gas-and-air mixture volumetric distribution under the main roof is quite time-consuming, and is often impossible and unsafe. This process is also very difficult to describe analytically, since it is not stationary, and even in the simplest cases requires the use of a complex mathematical apparatus [7]. Therefore, studying the air velocity and the volume of air flow dependence on the collapse parameters by some researchers [1, 8] should be performed in the laboratory with the use of physical modeling. However, in our opinion, complete kinematic and dynamic similarity of physical models cannot be ensured in real conditions. The same researchers propose calculation schemes (Figure-1) and note that it is expedient to divide the period of air flow formation during collapse into several stages (Figure-1): 1) the moment of air wave separation from the collapsed rocks of the main roof; 2) air movement through the seam of rocks under dynamic pressure; 3) air movement through the seam under the influence of differential pressure; 4) air movement through the long wall and a system of adjacent working under the influence of static differential pressure [1].

Thus, in accordance with the scheme shown in Figure-1, after the main roof collapse, the air wave should pass through the collapsed rocks of the bottom-hole area, the permeability of which by most optimistic forecasts is about 10^{-6} m^2 (10^9 mD), before the air wave reaches the bottom-hole area of the long wall and/or zonal workings. When considering this option of the collapse impact - the movement of air waves through fallen rocks of the immediate roof – the occurrence of dynamic effects on the bottom-hole zone is questionable. However, even in the absence of dynamic influence, one should expect some increase in methane concentration in the bottom-hole area of the long wall, the degree of which will depend on both methane concentration in part of the developed space adjacent to the bottom-hole area in the zone of collapse, and the volume of the methane-and-air mixture displaced from this zone.

It is also noted that in real terms, the pressure in the working area of the long wall during passage of the shock wave is influenced by several factors, the main being the following: geometrical parameters of the collapse, thickness and flexibility of the immediate roof collapsed rock, aerodynamic characteristics of the gob and the excavation complex in the long wall, the number of workings adjacent to the gob and the long wall.

METHODS

In our opinion, one should consider more dangerous situations caused by the main roof collapses, where propagation of air waves generated by the collapse formed directly in the bottom-hole area of the long wall and/or workings above the collapsed rocks of the immediate roof is possible. Formation of such situations is only possible in the geological conditions where the extracted thickness of the seam exceeds the thickness of the immediate roof by not less than 10-30%, i.e. with regards to loosening of the rocks after the immediate roof collapse the direct aerodynamic connection of the gob with the bottom-hole area is preserved, which provides the conditions for displacing into the latter of the methane-and-air mixture with high methane concentration.

VOL. 13, NO. 10, MAY 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

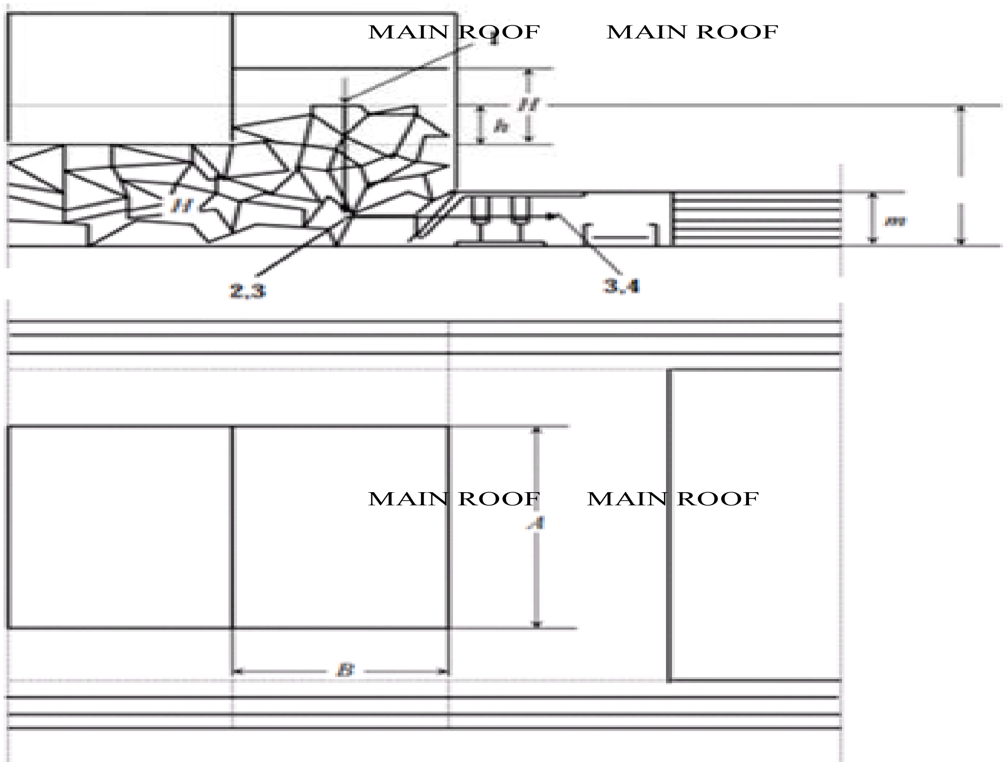

Figure-1. Computational scheme: *A, B* are the width and the pitch of the main collapse, respectively; m is the thickness of the developed seam; N_1 is the thickness of collapsed immediate roof; h is flexibility of the immediate roof; H is the height of main roof collapse; 1-4 are stages of air flow formation. [1]

In addition, it should be noted that the speed of the air stream will be significantly influenced by: the height (relative to the fall endpoint) the main roof collapses from; the area of the block that is first defined by the roof-caving increment.

The height of main roof caving will be the greatest when the thickest seams of the Vorkuta field, namely, the "Mosshny" and the "Troynoy" are developed. When long working faces are developed, the degree of danger of the carvings is determined by the following factors:

- the location of main roof caving (part of the long wall);
- the used scheme of extraction area preparation;
- the used ventilation scheme;
- volume of gas in the gob in the location of roof caving.

Considering that the return flow ventilation scheme with downwards air movement along the long wall is used for developing the "Powerful" seam, and zonal workings behind the long wall are compensated, the most hazardous conditions will occur in the zone of the long wall near the connection to the venting working, which is due to the following factors:

- main roof caving increment in this section is higher than that in the part of the long wall near connection to the venting working which is in the area of influence of the previously developed gob;
- along the long wall, methane concentration generally increases, reaching the maximum values in the end sections, in a dead-end part of the working and in the part of the gob adjacent to the bottom-hole area; and
- roof caving usually starts and develops along the long wall from the earlier worked-out gob, therefore with caving of the last blocks, a situation may develop where after block caving, free air movement will be possible only in the direction towards the bottom-hole area of the long wall and the dead-end of compensated vent working.

Thus, for the conditions of mining the "Mosshny" seam with the use of the considered schemes of preparation and ventilation, the most dangerous situation would be caving of the last block along the long wall near the vent working, provided that thickness of the immediate roof of the seam is less than extracted thickness of the seam by at least 20%. According to geological data,

ARPN Journal of Engineering and Applied Sciences

immediate roof thickness of the "Mosshny" seam is 1.5-2 m in the upper horizon, and it gradually increases up to 8-10 m in the bottom horizon. Thus, when the "Mosshny" seam with the average thickness of 4.1 m is mined, the possibility of sustainable aerodynamic connection is maintained with the immediate roof thickness up to 3.3-3.5 m, after which permeability of the gob at the border of the bottom-hole area starts increasing with increasing the immediate roof thickness.

It should be noted that formation and development of the air wave is influenced by the scheme of interaction between the main and immediate roof. In accordance with the generally accepted ideas about the nature of this interaction, three main cases of the main roof blocks caving are distinguished [2].

Thus, the proposed principal computational scheme, which, unlike the ones proposed by other authors [1, 5, 6], takes into account the nature of the interaction between the immediate and main roof, takes the form shown in Figure-2.

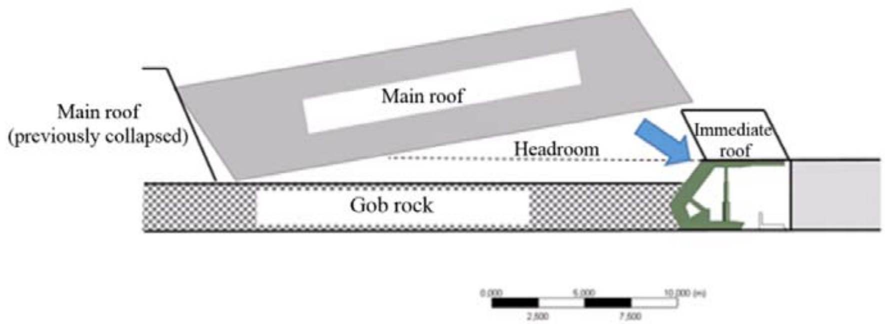

Figure-2. The proposed principal computational scheme.

Thus, the future calculations take into account the three-dimensional calculation scheme for the most dangerous situation. The last block is limited on two ends, and after caving air displacement is only possible into the dead-end part of the zonal working, to the connection and the bottom-hole area in the end of the long wall.

Considering the foregoing, for the conditions of mining the "Mosshny" seam the following ranges (and typical settings) of the initial conditions have been considered:

- unit caving height - 0.5 to 4 m (0.5 m, 2 m, 4 m);
- block size - 5 m to 50 m (5 m, 25 m, 50 m).

For all combinations of these parameters, speed, pressure and air wave influence range are calculated, after which the limits are set for the roof caving increments.

RESULTS

As an example of the obtained results, Figure-3 shows the velocity profiles formed during main roof caving, in the plane parallel to the seam stratification, passing through the bottom-hole area at the height of 2 m from the soil of the seam.

As one can see in Figure-3, the speeds in the air wave generated by roof caving may reach 33 m/s, however, the energy of the air wave even in the considered situation of direct relation between the gob and the bottom-hole area is compensated by the resistance created by obstacles in its path (caved rock, sections of mechanized support, etc.) and the speed in the part of the bottom-hole area from the side of the gob may reach 15-18 m/s, decreasing to 4 m/s at the distance of 1.5 m from the working face.

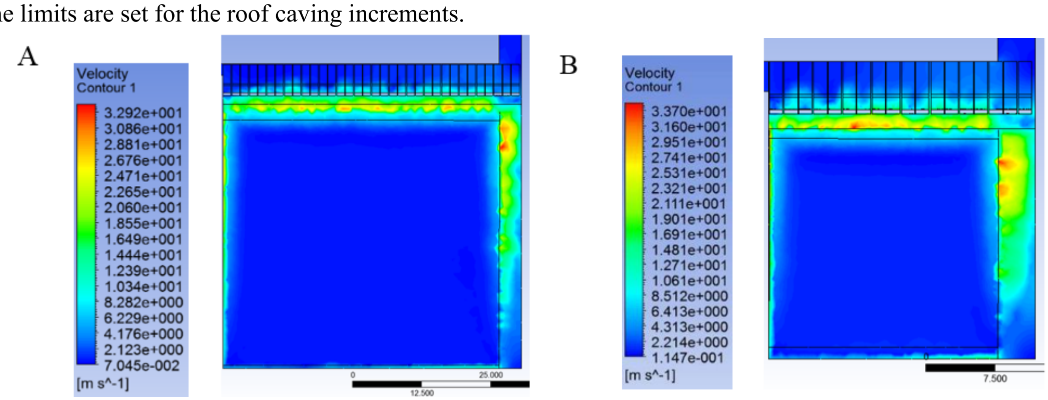

Figure-3. Velocity profiles of the air wave formed by caving of blocks of the main roof with the increments of: A) 50 m; B) 25 m.

ARPN Journal of Engineering and Applied Sciences

The performed assessment of critical roof caving increments that are dangerous due to the dynamic effect of the air wave and displacement of the methane-and-air mixture from the gob into the bottom-hole area showed that the necessary conditions for formation of dangerous dynamic effect were the following:

- significant hanging of the main roof;
- presence of the methane-and-air mixtures with high methane concentration in the caving area of the gob; and
- the minimum aerodynamic resistance of the gob after caving of the immediate roof.

DISCUSSIONS

It should be noted that the degree of harmful effects during main roof rock caving increases, ceteris paribus, with the increase in the thickness of the developed seams and the decrease in the thickness of the immediate roof. For example, for the conditions of developing the "Mosshny" seam, the greatest danger of dynamic influence will occur in case of main roof caving in the conditions of insufficient gob filling with caved rocks of the immediate roof, i.e. if the direct roof is much thinner than the thickness of the developed seam.

It is worth considering that these conditions are required but not sufficient for the emergence of a situation of technological gas concentration in the workings of the gob, as the level of danger during main roof caving is mainly determined by the roof caving increment, which determines the amount of displaced methane-and-air mixture, and by another even more significant factor, namely, methane concentration in the mixture. Taking into account the fact that methane concentration in the considered area of the gob adjacent to the bottom-hole area is a stochastic parameter defined by the joint action of the aggregate of influencing geological and mining factors, while its value actually determines the dangerous consequences of main roof caving in this aspect, determining the critical roof caving increment is impractical, and excluding the negative consequences of caving should be primarily based on reducing methane concentration in the area due to changing parameters of gob ventilation and degassing schemes.

The performed studies showed the need for a differentiated approach to choosing efficient schemes of gas emission management for protective layers (the "Fourth" and the "Fifth") and the main production seams (the "Mosshny" and the "Troynoy"), which had been determined by the substantial influence of first development on the state of both underworked and overworked seam [9, 11] and, as a consequence, changes in the conditions of geomechanical and gas-dynamic processes at excavation sites [10].

CONCLUSIONS

Based on the studies, it has been found that during the development of the "Troynoy" and the "Mosshny" seams, the highest danger of gas concentration associated with main roof caving is presented by the gob areas where mining is performed in the conditions of insufficient efficiency of the protective effect of undermining or in case of its complete absence. Of particular danger are the sections of mine fields where the extracted thickness of the seam exceeds the thickness of the immediate roof. It should be noted that the risk of gas concentration, ceteris paribus, increases dramatically when U-shaped (return flow) venting schemes are used, due to the low efficiency of venting the gob adjacent to the bottom-hole area, and the formation of elevated gas concentrations in the compensated parts of gobs.

In the conditions of efficient protective action of under working, stratification and increased fracturing of the main roof in the developed productive layers are ensured, which results in significant reduction of main roof caving increment and, therefore, in minimization of the danger of gas concentration associated with main roof caving.

During the development of the "Fourth" and the "Fifth" seams, the risk of gas concentration in gob workings during main roof caving is determined by caving increments, which, during the primary development exceed the caving increments for the conditions of the undermined rock mass. In such circumstances, one of the main measures for reducing the risk of gas concentration when working in the areas with hardly caving roofs is roof soil loosening, for example, hydro-micro-blasting, which also ensures gob improvement by reducing the concentration of strain in the areas of supporting resistance formed in the peripheral parts of the rock mass along the perimeter of the gob.

Thus, a necessary condition for avoiding gas concentration in gob workings during the periods of main roof caving in the steady state is excluding formation of zones with high methane concentrations in the parts of the gob that are directly adjacent to the bottom-hole area and have the length inside the worked-out space about main roof caving increment. In this area the main sources of methane release are seams of the underworked and overworked strata, while measures of reducing methane concentration should include both improving efficiency of gas sources' degassing, and improving efficiency of venting the specified area.

REFERENCES

[1] Smirnyakov V. V. 2014. Analiticheskaya otsenka aerodinamicheskih parametrov obrusheniya osnovnoi krovli [Analytical assessment of aerodynamic parameters of main roof caving]. Zapiski Gornogo Instituta. 207, 151-154.

[2] Borisov A. A. *et al*. 1983. Upravlenie gornym davleniem. [Mountain pressure management]. Textbook for technical schools. Moscow: Nedra. p. 168.

[3] Bubnov K. A., Remezov A. V. and Konovalov L. M. 2009. Studying accuracy of determining the immediate and main roof caving increments with the use of existing methods. Bulletin of KuzSTU. 5, 21-27.

[4] Belyaev V. I. and Timoshenko A. M. 2008. Issledovanie putei filtratsii metana iz prizaboinoi zoni razrabativaemogo plasta [Studying the ways of filtering methane from the bottom-hole area of the gob].Bulletin of the Research Center. 2, 88-94.

[5] Stepanov Y. A. 2011. Determining rock caving increments when undermined during underground mining operations. Bulletin of KuzSTU. 4, 44-45.

[6] Botvenko D. V. 2012. Issledovanie protsessov, obuslovlivayuschih ustoichivost i periodichnost obrusheniya porod krovli v ochistnih zaboyah na plastah pologo padeniya pri sovremennoi tehnologii ugledobichi [Studying the processes that determine stability and frequency of roof rock caving in working faces in low pitch seams in the use of modern technologies of coal mining].Bulletin of the Research Center. 2, 84-89

[7] Gryazev M.V., Kachurin N.M. and Vorobyev S.A. 2017. Mathematical Models of Gas-Dynamic and Thermophysical Processes in Underground Coal Mining at Different Stages of Mine Development. Zapiski Gornogo institute. 223, 99-108.

[8] Smirniakov V. V. and Smirniakova V. V. 2017. Formation peculiarities of caving zones as aerodynamic active branches of mine ventilation systems in pillar mining of coal beds. Jr. Of industrial pollution control. 33(1): 864-872.

[9] Polevshchikov G. Y., Shinkevich M. V., Kozyreva E. N. and Bryzgina O. V. 2008. Vliyanie protsessov razgruzki i sdvizhenii vmeschayuschih porod na videlenie metana iz razrabativaemogo plasta [Influence of unloading and shearing of enclosing rocks on methane release from the developed seam]. GIAB. 2, 139-143.

[10] Alehossein H. and Poulsen B. A. 2010. Stress analysis of longwall top coal caving. International Journal of Rock Mechanics and Mining Sciences. 47(1): 30-41.

[11] Leisle A.V. and Kovalski E.R. 2016. Complex extraction of methane and coal from thick coal seams. Research Journal of Pharmaceutical, Biological and Chemical Sciences. 7(3): 1660-1666.