Justification of technological parameters for underground mining of gas-bearing coal beds prone to spontaneous combustion

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Justification of technological parameters for underground mining of gas-bearing coal beds prone to spontaneous combustion

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Abstract. The article presents results of the numerical studies of aerodynamic processes in excavated sections of coal mines. The effect of the ventilation and degassing schemes and their parameters on the oxygen content and a danger of spontaneous coal combustion are described. The influence of geological and mining factors on the endogenous fire hazard of the coal bed prone to spontaneous combustion is analyzed. It is recommended to reduce endogenous fire hazards of mining flat gas-bearing coal beds of the Kuznetsk coal basin.

1. Introduction

In Russia, the main method of underground coal mining is the development of flat coal beds with long working faces. The use of modern high-performance equipment improves technical and economic indicators for coal mining in favorable mining and geological conditions [1, 2]. However, most Russian mines are dangerous in terms of gas – methane content. The problem of safe mining of gas-bearing strata has not been solved. One of the main ways to ensure safety in gas mines is to dilute methane to a safe concentration through ventilation. Most mines air and degas worked out spaces. These gas emission control schemes provide for the supply of significant volumes of air to the extraction section (up to 3600 m^3/min), which makes it possible to safely develop reserves in conditions of increased gas mobility [3]. However, most of the beds of the Kuznetsk coal basin are prone to spontaneous combustion; an increase in the air flow can lead to an increase in leakage in excavation areas and coal spontaneous combustion. It should be noted that for spontaneous coal combustion, it is necessary to have chemically active coal, oxygen supply, and heat accumulation. Thus, air leaks alone are not enough for spontaneous combustion of coal. However, if there is accumulation of crushed coal with critical volumes (layer thickness is more than 40 cm) and oxygen access, it can cause an endogenous fire.

The need for research aimed at studying gas dynamic processes is due to a significant change in their parameters (a lava length and a length of the excavation site), an increase in the withdrawn thickness of the strata and speeds of movement of the face, and an increase in air consumption in the excavation sites.

This article presents results of the numerical studies of aerodynamic processes in excavated sections of coal mines.

2. Research method

Methods of computational gas dynamics (the finite volume method) were used. The design scheme for conducting numerical studies is presented in Figure 1. The simulated excavation section includes: a mine, local preparatory workings, the worked out space and vertical degassing wells. The directions of movement of fresh and outgoing jets in the extraction section are shown in Figure 1. The studies were carried out for a combined ventilation scheme of the extraction section with isolated methane-air mixture removal to the rear fault by degassing the worked-out space by vertical degassing wells drilled from the earth's surface. The following parameters of the design scheme were changed: air flow in the extraction section (from 1500 to 3600 m^3/min), methane abundance in the extraction section (from 50 to 150 m^3/min), distance to the rear fault (from 150 to 450 m). The parameters of the space were set in accordance with the principles described in [4–5]. The permeability of the space depends on a number of geological and mining factors: power of the bed, speed of face movement, physicomechanical properties of roof rocks [9–12]. Correct determination of the parameters (permeability and porosity) is important when conducting research on air-gas-dynamic processes and studying the influence of various factors on the spontaneous coal combustion, since the space is the main site of endogenous fires.
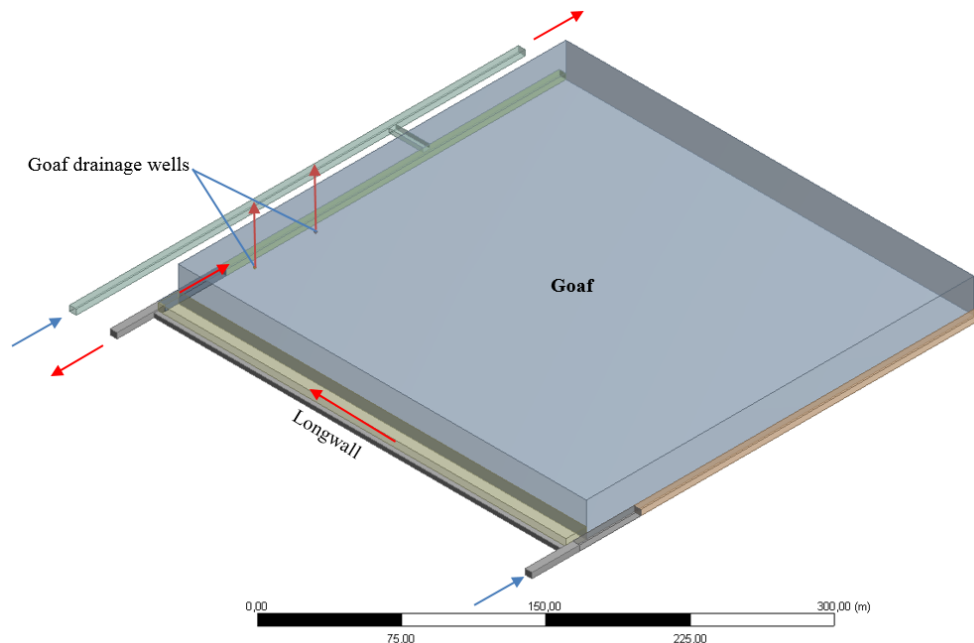

Figure 1. Design scheme for numerical studies

3. Results and discussion

The study determined the distribution fields of methane, oxygen and air speeds in the excavation section. Figure 2 shows the fields of oxygen concentrations in the planes parallel to the bedding, located at a distance of 2 m (Figure 2, a) and 20 m (Figure 2, b) from the soil. In accordance with current regulatory documents, the spaces should have an oxygen concentration of less than 10 %, and the areas isolated due to the occurrence of foci of self-heating or combustion should be less than 3 %. Figure 2 shows that a considerable length of the section has a high oxygen concentration due to the increased permeability. A significant part of the space has a high methane concentration.

Despite the presence of zones with a high oxygen concentration, spontaneous combustion of coal can occur only if all three conditions of spontaneous combustion are met during the incubation period (40–60 days). Since the working face and the ventilated area are constantly moving, only periods of lava stagnation caused long downtime of the equipment are dangerous. Analysis of the working faces of the Kuzbass mines shows that such periods are frequent and the work of almost all the working faces is characterized by low stability. The greatest danger is the period of completion of works associated with

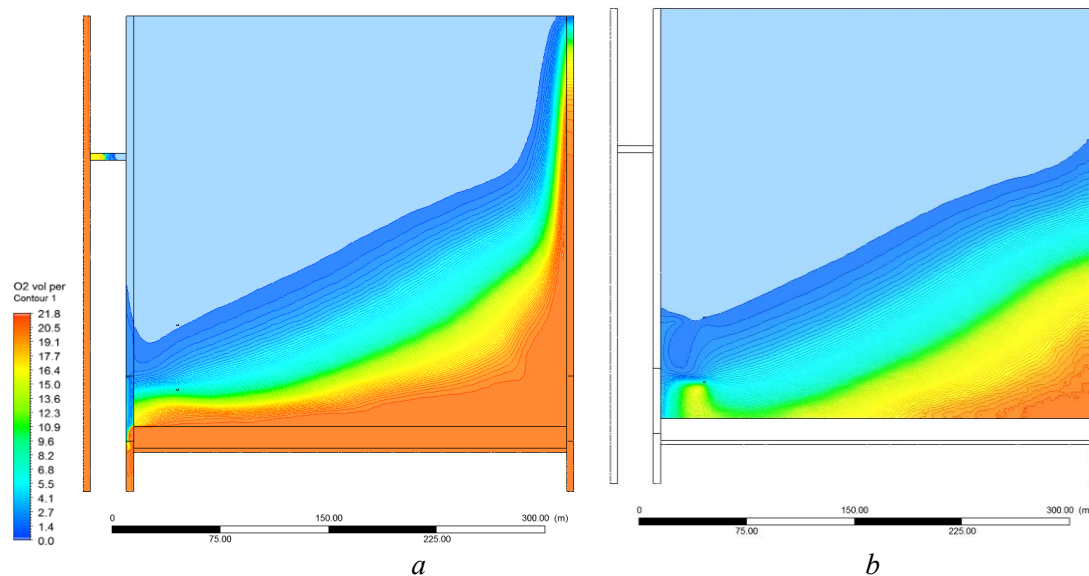the remounting of equipment. Its planned duration is 40-60 days, and the actual duration is 90 days or more.

Figure 2. Oxygen Distribution Fields, %

A high risk of spontaneous combustion is typical of the marginal parts of the massif and pillars, which accumulate disintegrated coal [13–16]. The destruction of coal is caused by the simultaneous influence of reference pressure and increased pressure from the pillars left along the mined-out coal bed [17–20].

4. Conclusion

The studies made it possible to establish the distribution of oxygen in the mined-out space of the excavation site when using the combined scheme for airing and degassing the mined-out space by wells drilled from the earth's surface. The most dangerous spontaneous combustion zones located on the side of the air supply were identified. The studies have shown a danger of long downtime of the working face and an increased risk of spontaneous combustion during the dismantling of equipment. It was also established that the greatest danger is created by accumulated destroyed coal formed during the destruction of pillars of the mine-out area in the zones of joint action of the reference pressure and increased pressure from the pillars left along the mined-out coal bed.

The studies have shown the possibility of applying the methods of computational gas dynamics to determine rational parameters of the ventilation and degassing schemes of excavation sites during mining of reservoirs prone to spontaneous combustion and to identify hazardous areas.

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