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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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[1]Non-profit Joint-stock Company Abylkas Saginov Karaganda Technical University, Karaganda, Kazakhstan;
[2]Satbayev University, Almaty, Kazakhstan.
E-mail: sattarovags@mail.ru

ENSURING HEALTHY AND SAFE WORKING CONDITIONS IN BREAKAGE FACE WITH DIRECT-FLOW VENTILATION SCHEME

Spatayev Nurbek Dairbekovich — Candidate of technical sciences. Associated professor of the Department of Mine Aerology and Occupational Safety. Abylkas Saginov Karaganda Technical University NJSC. 100027. Ave. Nursultan Nazarbayev, 56, Karaganda, Kazakhstan
E-mail: spatayev.nurbek@bk.ru, https://orsid.org/0000-0003-1967-7698;
Sattarova Gulmira Saparovna — Candidate of technical sciences. Associated professor of the Department of Mine Aerology and Occupational Safety. Abylkas Saginov Karaganda Technical University NJSC. 100027. Ave. Nursultan Nazarbayev, 56, Karaganda, Kazakhstan
E-mail: sattarovags@mail.ru. https://orsid.org/0000-0002-9764-2311;
Nurgaliyeva Assel Danialovna — Candidate of technical sciences. Associated professor of the Department of Mine Aerology and Occupational Safety, Abylkas Saginov Karaganda Technical University NJSC. 100027. Ave. Nursultan Nazarbayev, 56, Karaganda, Kazakhstan
E-mail: a_nurgaliyeva@inbox.ru, https://orsid.org/0000-0003-3382-4463;
Balabas Lidia Khizirovna — Candidate of technical sciences, Associated professor of the Department of Mine Aerology and Occupational Safety. Abylkas Saginov Karaganda Technical University NJSC. 100027. Ave. Nursultan Nazarbayev, 56, Karaganda, Kazakhstan
E-mail: l.balabas@yandex.ru, https://orsid.org/ 0000-0002-1744-4412;
Batessova Firuza Kaisarbekovna — Candidate of technical sciences, Associated professor of the Department of Engineering Systems and Networks. Satbayev University, 50013, 22a Satpaev Street, Almaty, Kazakhstan
E-mail: firuza_78@mail.ru, https://orcid.org/0000-0003-3784-1009.

Abstract. One of the most dangerous production factors of coal enterprises is the methane gas emission when performing technological processes for the extraction of coal seams. This hazardous production factor is directly related to the risk of gassing underground mine workings. Such an aero-gas situation can lead to ignition, and further explosion of the methane-air environment that will lead to significant human and material losses. In order to ensure safe working conditions in coal mines, it is necessary to organize and to ensure ventilation of all mine workings. However, not all methods of controlling gas evolution are effective. To solve this problem, the authors of this paper propose to take into consideration the leakage of air supplied to the breakage face through the collapsed coal-rock massif of the mined-out space when controlling gas emission of the extraction area. For this purpose, there was studied the stope and the supported ventilation working gas state, depending on the conditions of ventilation and air leakage through the mined-out area of the longwall face. In addition, the aerodynamic parameters of the stope and maintained workings and the dynamics of air leaks through the worked-out space massif were studied. There were carried out experiments in the mines of the Karaganda region, where, alongside with the adverse ventilation scheme, the direct-flow ventilation was also used. Thus, this paper presents the results of studies of the aero-gas-dynamics features for extraction areas with the straight-through ventilation scheme of the stope. As a result of the research, a quasi-network model of the production area was built and an algorithm was developed for determining air leaks through the collapsed massif of mined-out space.

Keywords: quasi-network model, worked-out space, air leaks, depressions residuals, straight-through ventilation scheme

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[1] «Әбілқас Сағынов атындағы Қарағанды техникалық университеті» Коммерциялық емес акционерлік қоғамы, Қарағанды, Қазақстан;

[2]Сәтбаев университеті, Алматы, Қазақстан.
E-mail: sattarovags@mail.ru

ТУРА АҒЫМДЫ ЖЕЛДЕТУ СХЕМАСЫ БАР ТАЗАРТУ КЕНЖАРЛАРЫНДА ДҰРЫС ЖӘНЕ ҚАУІПСІЗ ЕҢБЕК ЖАҒДАЙЛАРЫН ҚАМТАМАСЫЗ ЕТУ

Спатаев Нурбек Даирбекович — техника ғылымдарының кандидаты, аға оқытушы, Әбілқас Сағынов атындағы Қарағанды техникалық университеті. 100027. Нұрсұлтан Назарбаев көшесі, 56, Қарағанды, Қазақстан
E-mail: spatayev.nurbek@bk.ru. https://orsid.org/0000-0003-1967-7698;

Саттарова Гульмира Сапаровна — техника ғылымдарының кандидаты, қауымдастырылған профессор, Әбілқас Сағынов атындағы Қарағанды техникалық университеті. 100027. Нұрсұлтан Назарбаев көшесі, 56, Қарағанды, Қазақстан
E-mail: sattarovags@mail.ru, https://orsid.org/0000-0002-9764-2311;

Нургалиева Асель Данияловна — техника ғылымдарының кандидаты, қауымдастырылған профессор, Әбілқас Сағынов атындағы Қарағанды техникалық университеті, 100027, Нұрсұлтан Назарбаев көшесі, 56, Қарағанды, Қазақстан
E-mail: a_nurgaliyeva@inbox.ru, https://orsid.org/0000-0003-3382-4463;

Балабас Лидия Хизировна — техника ғылымдарының кандидаты, қауымдастырылған профессор, Әбілқас Сағынов атындағы Қарағанды техникалық университеті. 100027. Нұрсұлтан Назарбаев көшесі. 56. Қарағанды. Қазақстан
E-mail: l.balabas@yandex.ru, https://orsid.org/ 0000-0002-1744-4412;

Батесова Фируза Кайсарбековна — техника ғылымдарының кандидаты, қауымдастырылған профессор. Сәтбаев университеті, 50013, Сәтбаев көшесі, 22а, Алматы, Қазақстан
E-mail: firuza_78@mail.ru, https://orcid.org/0000-0003-3784-1009.

Аннотация. Көмір кәсіпорындарының ең қауіпті өндірістік факторларының бірі көмір қабаттарын қазу бойынша технологиялық процестерді жүргізу кезінде метан газының бөлінуі болып табылады. Бұл қауіпті өндірістік фактор жерасты тау-кен қазбаларының газдану қаупімен тікелей байланысты болады. Мұндай аэрогаз ортасының болуы тұтануға, ал келешекте метан-ауа ортасының жарылуына, адам шығыны мен материалдық шығынға әкеліп соғуы ықтимал. Көмір шахталарында қауіпсіз еңбек жағдайларын қамтамасыз ету үшін барлық тау-кен қазбаларын желдетуді ұйымдастыру және қамтамасыз ету қажет. Дегенмен, газ шығаруды басқарудың барлық әдістері тиімді емес. Бұл мәселені шешу үшін мақала авторлары қазып алу учаскесінің газдың бөлінуін бақылау кезінде қазылған кеңістіктің опырылған көмір-таужыныс массиві арқылы тазарту кенжарына берілетін ауаның кемуін ескеруді ұсынады. Осы мақсатқа орай лаваның қазылған кеңістігі арқылы желдету және ауаның кемуі жағдайларына байланысты тазарту кенжарының және күтіп ұсталған желдетуші қазындыларының газ жағдайына зерттеулер жүргізілді. Бұдан басқа, тазарту және күтіп ұсталған қазбаларының аэродинамикалық параметрлері және қазылған кеңістік массиві арқылы ауаның кемуі динамикасы зерттелді. Эксперименттік зерттеулер Қарағанды көмір бассейнінің шахталарында жүргізілді, мұнда кері ағымды желдету схемасымен қатар тура ағымды желдету схемасы да қолданылады. Сонымен, бұл мақалада тазарту кенжарын желдетудің тура ағымды схемасы бар қазып алу учаскелеріне арналған аэрогазодинамика ерекшеліктерін зерттеу нәтижелері келтірілген. Зерттеу нәтижесінде тазарту учаскесінің квазижелілік моделі құрылды және қазылған кеңістіктің опырылған массиві арқылы ауаның кемуін есептеу алгоритмі жасалды.

Түйін сөздер: квазижелілік модель, қазылған кеңістік, ауаның кемуі, депрессияның үйлеспеушілігі, желдетудің тура ағымды схемасы

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[1]НАО «Карагандинский технический университет имени Абылкаса Сагинова», Караганда, Казахстан;
[2]Сатбаев университет, Алматы, Казахстан.
E-mail: sattarovags@mail.ru

ОБЕСПЕЧЕНИЕ ЗДОРОВЫХ И БЕЗОПАСНЫХ УСЛОВИЙ ТРУДА В ОЧИСТНЫХ ЗАБОЯХ С ПРЯМОТОЧНОЙ СХЕМОЙ ПРОВЕТРИВАНИЯ

Спатаев Нурбек Даирбекович — кандидат технических наук, старший преподаватель, НАО Карагандинский технический университет имени Абылкаса Сагинова. 100027. проспект Нурсултана Назарбаева, 56, Караганда, Казахстан
E-mail: spatayev.nurbek@bk.ru, https://orsid.org/0000-0003-1967-7698;

Саттарова Гульмира Сапаровна — кандидат технических наук, доцент, НАО Карагандинский технический университет имени Абылкаса Сагинова. 100027. проспект Нурсултана Назарбаева, 56, Караганда, Казахстан
E-mail: sattarovags@mail.ru, https://orsid.org/0000-0002-9764-2311;

Нургалиева Асель Данияловна — кандидат технических наук, доцент, НАО Карагандинский технический университет имени Абылкаса Сагинова. 100027. проспект Нурсултана Назарбаева, 56, Караганда, Казахстан

E-mail: a_nurgaliyeva@inbox.ru, https://orsid.org/0000-0003-3382-4463;

Балабас Лидия Хизировна — кандидат технических наук, доцент, НАО Карагандинский технический университет имени Абылкаса Сагинова. 100027. проспект Нурсултана Назарбаева, 56, Караганда, Казахстан

E-mail: l.balabas@yandex.ru, https://orsid.org/ 0000-0002-1744-4412;

Батесова Фируза Кайсарбековна — кандидат технических наук, ассоциированный профессор. Сатбаев университет. 50013. улица Сатпаева, 22а, Алматы, Казахстан

E-mail: firuza_78@mail.ru, https://orcid.org/0000-0003-3784-1009.

Аннотация. Одним из наиболее опасных производственных факторов угольных предприятий является выделение газа метана при ведении технологических процессов по выемке угольных пластов. Данный опасный производственный фактор непосредственно связан с риском загазовывания подземных горных выработок. Наличие такой аэрогазовой обстановки может привести к воспламенению, а в дальнейшем и к взрыву метановоздушной среды, приводящим к значительным людским и материальным потерям. В целях обеспечения безопасных условий труда на угольных шахтах необходимо организовывать и обеспечивать проветривание всех горных выработок. Однако не все способы управления газовыделением являются эффективными. Для решения данной задачи авторами статьи предлагается при управлении газовыделением выемочного участка учитывать утечки подаваемого в очистной забой воздуха через обрушенный углепородный массив выработанного пространства. С этой целью были проведены исследования газового состояния очистного забоя и поддерживаемой вентиляционной выработки в зависимости от условий проветривания и утечек воздуха через выработанное пространство лавы. Кроме того, были исследованы аэродинамические параметры очистной и поддерживаемой выработки и динамика утечек воздуха через массив выработанного пространства. Экспериментальные исследования проводились на шахтах Карагандинского угольного бассейна, где наряду с возвратноточной схемой проветривания применяется и прямоточная. Так, в данной статье приведены результаты исследований особенностей аэрогазодинамики для выемочных участков, имеющих прямоточную схему проветривания очистного забоя. В результате исследований построена квазисетевая модель очистного участка и разработан алгоритм расчета утечек воздуха через обрушенный массив выработанного пространства.

Ключевые слова: квазисетевая модель, выработанное пространство, утечки воздуха, невязки депрессии, прямоточная схема проветривания

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Introduction

Accidents that have occurred in coal mines indicate that the most dangerous in terms of methane emission are production areas, where the highest concentration of mining operations and the likelihood of gassing the extraction areas workings take place. The increased content of methane in the workings adjacent to the stope creates a risk of ignition and explosion of the gas-air mixture causing injuries to workers of varying severity, up to death, destruction of the mine working supports, mechanisms and equipment (Yermakov et al., 2018: 6). The analysis of literature sources has shown that the measures used in various coal basins to eliminate gassing the underground mine workings are not always sufficient to ensure safe working conditions for miners. Formation of the aero-gas situation in the bottomhole area of the longwall face largely depends on the filtration properties of the collapsed massif. At the same time, permeability of the mined-out area of the longwall face is affected not only by mining and geological factors but also by the rate of the stope advance and the main roof of the formation step of collapse.

The main initial data for substantiating methane emission control methods is the information of the state of the gas and aerodynamic situation of the stope, adjacent workings that outline the excavation area, including the worked-out space.

In order to develop the most effective aerodynamic methods of preventing gas contamination of the stoping and supported ventilation workings, it is necessary to study their gas state depending on the conditions of ventilation and air leakage through the collapsed coal-rock massif of the mined-out area of the longwall face; in addition, to study the aerodynamic parameters of the stoping and supported ventilation workings of the excavation area, as well as the dynamics of air leaks through the collapsed coal rock massif of the mined-out area of the longwall face.

The actual aerodynamic parameters of mine workings and the state of their ventilation were studied in the mines of the Karaganda region that is located in the Republic of Kazakhstan and is one of the largest coal basins in the world. The Karaganda coal deposit is distinguished by a rather high natural methane content of the seams. All the mines of the Karaganda basin are classified as super-category for methane in terms of relative methane abundance, which directly affects the safety of mining operations. To provide healthy and safe working conditions for workers, it is first of all necessary to ensure effective ventilation of mine workings in development and excavation areas.

The main scheme of ventilation of the working faces in the mines of the Karaganda basin is a adverse ventilation scheme. In order to increase the volume of coal mined in longwalls, to reduce the cost of preparing excavation areas by reusing supported ventilation workings, in some mines of the basin, alongside with a return flow, a straight-through ventilation scheme of excavation areas is also used. As a result of mining coal seams using a direct-flow ventilation scheme, a significant size and volume goaf area of the collapsed rock massif are formed behind the stope, which affect the aerodynamic parameters and the ventilation mode of the excavation area (Assainov et al., 2021: 6).

At the same time, developing the coal seams using a straight-through ventilation scheme in the Karaganda region showed its rather high efficiency and the possibility of providing safer working conditions for miners (Kaliyev et al., 1987: 2; Drizhd et al., 1991: 2).

One of the main factors in the efficiency of ventilation of the excavation area is the flow rate of air supplied to the stope and its leakage through the collapsed coal massif (Cao et al., 2017: 4). Air leaks through the goaf carry a significant amount of methane from the longwall to the ventilation opening, but at the same time reduce the amount of air to ventilate the bottomhole area of the stope. In the area where the longwall face mates with the ventilation opening, the air flow can change its speed and even change the direction of its movement. As a result, this can lead to increasing the methane content at the junction of the longwall with the ventilation working, that is, the gassing of the junction area. (Liang et al., 2018: 11). Considering the potential danger of air leaks through a fractured coal-rock mass to the formation of gas contamination in the areas of a stope and ventilation supported working when using a direct-flow ventilation scheme, it is necessary to have a clear idea of the methods and results of controlling the aero-gas situation in the extraction areas of coal mines (Shevchenko et al., 2020: 5; Levin et al., 2018: 8).

The effect of goaf on the formation of air leaks through the collapsed massif is not unambiguous. Conventionally, two areas can be distinguished that affect the air flow into the ventilation opening.

The first area is associated with the processes occurring during the main roof caving, and corresponds to the step of roof collapse. This process is periodically repeated, cyclically changing the filtration characteristics of the collapsed massif. Air leaks from the stope into the ventilation opening can change their size and direction, which has a negative impact on the ventilation mode of the bottomhole area of the longwall in the zone of junction with the ventilation opening.

The second area is a part of the goaf massif from the place of complete collapse of the main roof of the seam that extends further into the massif. In this area, there are no longer any extreme values of air leakage from the stope into the supported ventilation opening. This is due to the fact that caking and compaction of the collapsed roof rocks leads to gradual decreasing the voidness of the mined-out space, which has a decisive effect on changing the filtration characteristics of the collapsed coal-rock massif.

In the conditions of the operating Kostenko and Stakhanovskaya mines, gas-air surveys were carried out in the workings of the excavation areas with measuring such indicators as the volumetric content of methane in the mine atmosphere, the speed of movement and air consumption, as well as the depression between points. In addition, measurements were made of the amount of air inflows into the ventilation opening through the collapsed massif of the longwall.

Analyzing and processing the obtained data made it possible to establish a certain dependence of changing air inflows into the supported working, which satisfactorily agrees with the experimental data.

The stope working is located in an unstable ventilation zone and is a diagonal element with a straight-through ventilation scheme of the excavation area. Thus, studying and analyzing the process of air leaks passing through the goaf is important (Zhou et al., 2018: 4, F-l Wu et al., 2019: 10). To study the effect of the aerodynamic parameters of the workings of the excavation area and the collapsed coal rock massif on the formation and nature of the distribution of air flows, a quasi-network model of the mined-out area of the stope was used, which reflected the real state of the rock massif.

The purpose of this article is to familiarize with the quasi-network model of the excavation area, which makes it possible to simulate various methods of controlling gas release in the case of a straight-through ventilation scheme of the excavation area. The presented calculation algorithm allows managers and specialists of coal mines controlling the aerodynamic parameters of the stope and ventilation workings, as well as the goaf space to provide healthy and safe working conditions for miners.

Materials and basic methods

The nature of distribution of air flows in the excavation area with a straight-through ventilation scheme depends on the aerodynamic characteristics of the collapsed coal-rock massif of the mined-out area of the longwall and the contour workings.

The straight-through ventilation scheme of the excavation area is a simple diagonal connection (Figure 1), where the stope (element 3–4) is a diagonal element in which the unstable ventilation zone is located. The direction of air movement through the stope and air leaks from the longwall through the collapsed massif of mined-out space to the supported ventilation opening is possible if the following inequality is fulfilled:

$$\frac{R_{1,2} + R_{2,3}}{R_{1,4}} < \frac{R_{3,5}}{R_{4,5}}, \tag{1}$$

where

$R_{1,2}$, $R_{1,4}$, $R_{2,3}$ –is the aerodynamic resistance of the conveyor and ventilation workings of the extraction area with an air intake, daPa s^2/m^6;

$R_{3,5}$ –is the aerodynamic resistance of the worked-out space of the breakage face, daPa s^2/m^6;

$R_{4,5}$ –is the aerodynamic resistance of the supported ventilation working with the air upcast, daPa s^2/m^6.

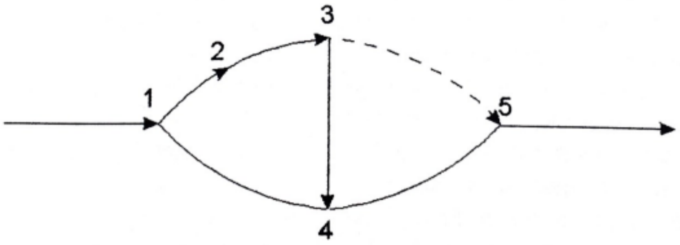

Figure 1 – Straight-through ventilation scheme of the extraction area

The values of aerodynamic resistances of expression (1) are not constant values. Changes in aerodynamic resistance as the coal seam is mined and the line of the stope advances can lead to equality of the ratios in the expression or even a change in the inequality sign. In this case, there will be a change in the direction of air movement along the excavation area and an overturning of the air jet at the area where the longwall meets the supported ventilation opening.

To study the effect of the aerodynamic characteristics of the collapsed massif and the existing workings on the nature of gas-air flows distribution, it is proposed to use a quasi-network model of the mined-out space of the longwall (Levitsky, 2012) shown in Figure 2.

The point of the breakage face junction with the supported ventilation working is taken as the origin of the coordinate system. The X-axis passes along the supported ventilation working, the Y-axis along the line of the stope, and the Z-axis perpendicular to the plane of the coal seam. The number of branches of air leaks from the stope to the supported ventilation working from 1 to n depends on the length of the longwall and the size of the goaf. Thus, we have a complex ventilation scheme with 3n branches, 2n+1 nodes and n independent contours.

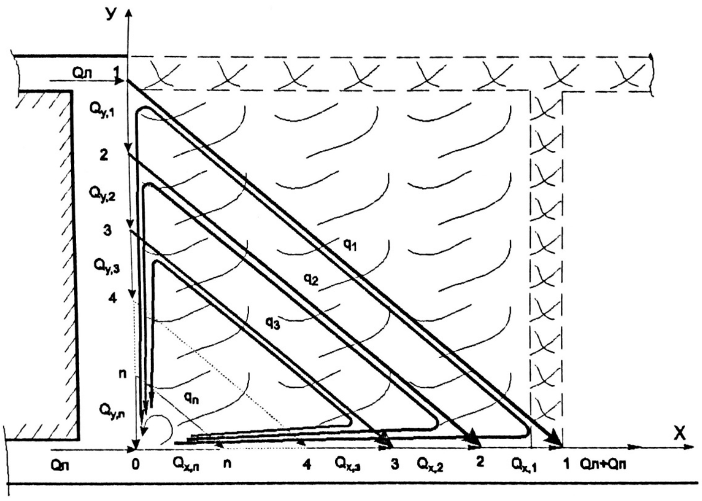

Figure 2 – Quasi-network model of the longwall goaf

The system of equations describing the quasi-network model with the set direction of bypassing the contours, has the form:

$$\begin{cases} \sum_{i=1}^{n} R_{y,i}\,Q_{y,i}^{2} + \sum_{i=1}^{n} R_{x,i}\,Q_{x,i}^{2} - r_1 q_1 = 0; \\ \sum_{i=2}^{n} R_{y,i}\,Q_{y,i}^{2} + \sum_{i=2}^{n} R_{x,i}\,Q_{x,i}^{2} - r_2 q_2 = 0; \\ \sum_{i=3}^{n} R_{y,i}\,Q_{y,i}^{2} + \sum_{i=3}^{n} R_{x,i}\,Q_{x,i}^{2} - r_3 q_3 = 0; \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ \sum_{i=n}^{n} R_{y,i}\,Q_{y,i}^{2} + \sum_{i=n}^{n} R_{x,i}\,Q_{x,i}^{2} - r_n q_n = 0, \end{cases} \tag{2}$$

where

$Q_{y,i}$ is the air flow rate in the i-th section of the breakage fact, m^3/s;

$Q_{x,i}$ is the air flow rate in the i-th section of the supported ventilation working, m^3/s;

q_i is the air leakage in the i-th direction through the collapsed massif of the worked-out space, m^3/s;

$R_{y,i}$ is the aerodynamic resistance of the i-th section of the breakage face, daPa·s^2/m^6;

$R_{x,i}$ is the aerodynamic resistance of the i-th section of the supported working, daPa·s^2/m^6;

r_i is the aerodynamic resistance of the i-th direction through the collapsed massif of the worked-our space, daPa·s/m^3.

Provided that the air leaks from the longwall through the collapsed goaf are independent, the amount of air entering the corresponding section of the quasi-network model is determined by:

– for the longwall:

$$Q_{y,1} = Q_{л} - q_1;$$

$$Q_{y,2} = Q_{л} - (q_1 + q_2);$$

$$Q_{y,3} = Q_{л} - (q_1 + q_2 + q_3);$$

$$\ldots\ldots\ldots\ldots \tag{3}$$

$$Q_{y,1} = Q_{\text{л}} - \sum_{j=1}^{i} q_j, \quad i = \overline{1,n};$$

– for the supported ventilation working:

$$Q_{x,1} = (Q_l + Q_p) - q_1;$$

$$Q_{x,2} = (Q_l + Q_{\text{п}}) - (q_1 + q_2);$$

$$Q_{x,3} = (Q_l + Q_p) - (q_1 + q_2 + q_3); \qquad (4)$$

$$\cdot \; \cdot \; \cdot \; \cdot \; \cdot \; \cdot \; \cdot \; \cdot \; \cdot \; \cdot \; \cdot \; \cdot \; \cdot$$

$$Q_{x,i} = (Q_l + Q_p - \sum_{j=1}^{i} q_j, \quad i = \overline{1,n},$$

where

Q_l is the air amount supplied for the longwall ventilation, m^3/s;

Q_p is the air amount supplied into the supported ventilation working for the upcast fresh, m^3/s.

When substituting (3) and (4) into expression (2), there is obtained a closed system of equations for unknown independent air flow rates qi, $i=1,n$, which satisfies the first and second laws of ventilation networks (Levitsky, 2012; Levitsky et al., 2018):

$$\begin{cases} \sum_{i=1}^{n} R_{y,i}\left(Q_{\text{л}} - \sum_{j=1}^{i} q_j\right)^2 + \sum_{i=1}^{n} R_{x,i}\left[\left(Q_{\text{л}} + Q_n\right) - \sum_{j=1}^{i} q_j\right]^2 - r_1 q_1 = 0; \\ \sum_{i=2}^{n} R_{y,i}\left(Q_{\text{л}} - \sum_{j=1}^{i} q_j\right)^2 + \sum_{i=2}^{n} R_{x,i}\left[\left(Q_{\text{л}} + Q_n\right) - \sum_{j=1}^{i} q_j\right]^2 - r_2 q_2 = 0; \\ \sum_{i=3}^{n} R_{y,i}\left(Q_{\text{л}} - \sum_{j=1}^{i} q_j\right)^2 + \sum_{i=3}^{n} R_{x,i}\left[\left(Q_{\text{л}} + Q_n\right) - \sum_{j=1}^{i} q_j\right]^2 - r_3 q_3 = 0; \\ \cdot \; \cdot \\ \sum_{i=n}^{n} R_{y,i}\left(Q_{\text{л}} - \sum_{j=1}^{i} q_j\right)^2 + \sum_{i=n}^{n} R_{x,i}\left[\left(Q_{\text{л}} + Q_n\right) - \sum_{j=1}^{i} q_j\right]^2 - r_n q_n = 0. \end{cases} \qquad (5)$$

The solution of this non-linear system of equations using the Newton linearization method makes it possible to determine the calculated air flow rates for each section of the breakage face. The calculated values may not always coincide with the actual values of the air flow in the longwall. This is caused by the fact that air leaks through the worked-out space significantly affect the degree of turbulence of air movement and the coefficient of aerodynamic resistance of the workings, which, with a direct-flow ventilation scheme, leads to changing the air flow along the length of the stope. Thus, the calculated values of the air flow require adjustment.

To determine depression residuals, there were set approximate values of the air leaks $q_i^*, i = \overline{1,n}$ under the condition that $Q_{\text{л}} \geq q_1^* + q_2^* + q_3^* + \cdot \cdot \cdot + q_n^*$. Having substituted them in (5), there are determined depression residuals Δh$_i$, $i = \overline{1,n}$ on all the contours of the quasi-network model.

Formation of the linear system of equations for calculation corrections Δq$_i$, $i = \overline{1,n}$ to the accepted approximate values of the air flow rates for leaks $q_i^*, i = \overline{1,n}$ is made according to (Levitsky et al., 2018) on the basis of (5). After necessary transformations, there will be obtained the linear system of equations of the form:

$$\begin{cases} (C_1+0{,}5r_1)\Delta q_1 + C_2\Delta q_2 + C_3\Delta q_3 + \cdots + C_n\Delta q_n = 0{,}5\Delta h_1; \\ C_2\Delta q_1 + (C_2+0{,}5r_2)\Delta q_2 + C_3\Delta q_3 + \cdots + C_n\Delta q_n = 0{,}5\Delta h_2; \\ C_3\Delta q_1 + C_3\Delta q_2 + (C_3+0{,}5r_3)\Delta q_3 + \cdots + C_n\Delta q_n = 0{,}5\Delta h_3; \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ C_n\Delta q_1 + C_n\Delta q_2 + C_n\Delta q_3 + \cdots + C_n\Delta q_n + (C_n+0{,}5r_n)\Delta q_n = 0{,}5\Delta h_n, \end{cases} \tag{6}$$

where Δh_1, Δh_2, Δh_3, ···, Δh_n are depression residuals on the corresponding contours of the calculating scheme, daPa.

From system (6), there are found the required corrections Δq_i, $i=\overline{1,n}$. Taking into account the corrections, there are corrected the accepted before values of air leaks q_i^*, $i=\overline{1,n}$ using the formula:

$$q_i = q_i^* + \Delta q_i,\ i=\overline{1,n}. \tag{7}$$

Figure 3 shows how to calculate air leaks through the goaf.

Initially (block 1), the actual values of the working sections and the amount of air passing through them are determined.

Next, the approximate values of air leaks q_i through the goaf space (block 2) are set and the fulfillment of the condition for the total number of leaks $\sum q_i \le Q_l$ is checked.

If the condition for the amount of leaks is not met, then it is necessary to check the correctness of the originally set leak values and, if necessary, to correct them (block 3).

If the condition on the amount of leaks is met, then the air flow rates are determined in the areas of the treatment $Q_{x,i}$, and the maintained ventilation $Q_{y,i}$ of the quasi-network model and the corresponding aerodynamic resistances $R_{x,i}$, $R_{y,i}$, as well as the aerodynamic resistances of the directions of movement of air leaks through the collapsed massif r_i.

Block 5 involves formation of a system of equations for unknown independent air flow rates q_i based on the first and second laws of ventilation networks.

After solving the specified system of equations, the depression residuals Δh_i are determined for all contours of the calculation scheme (block 6) and their evaluation is carried out with a given calculation accuracy (block 7).

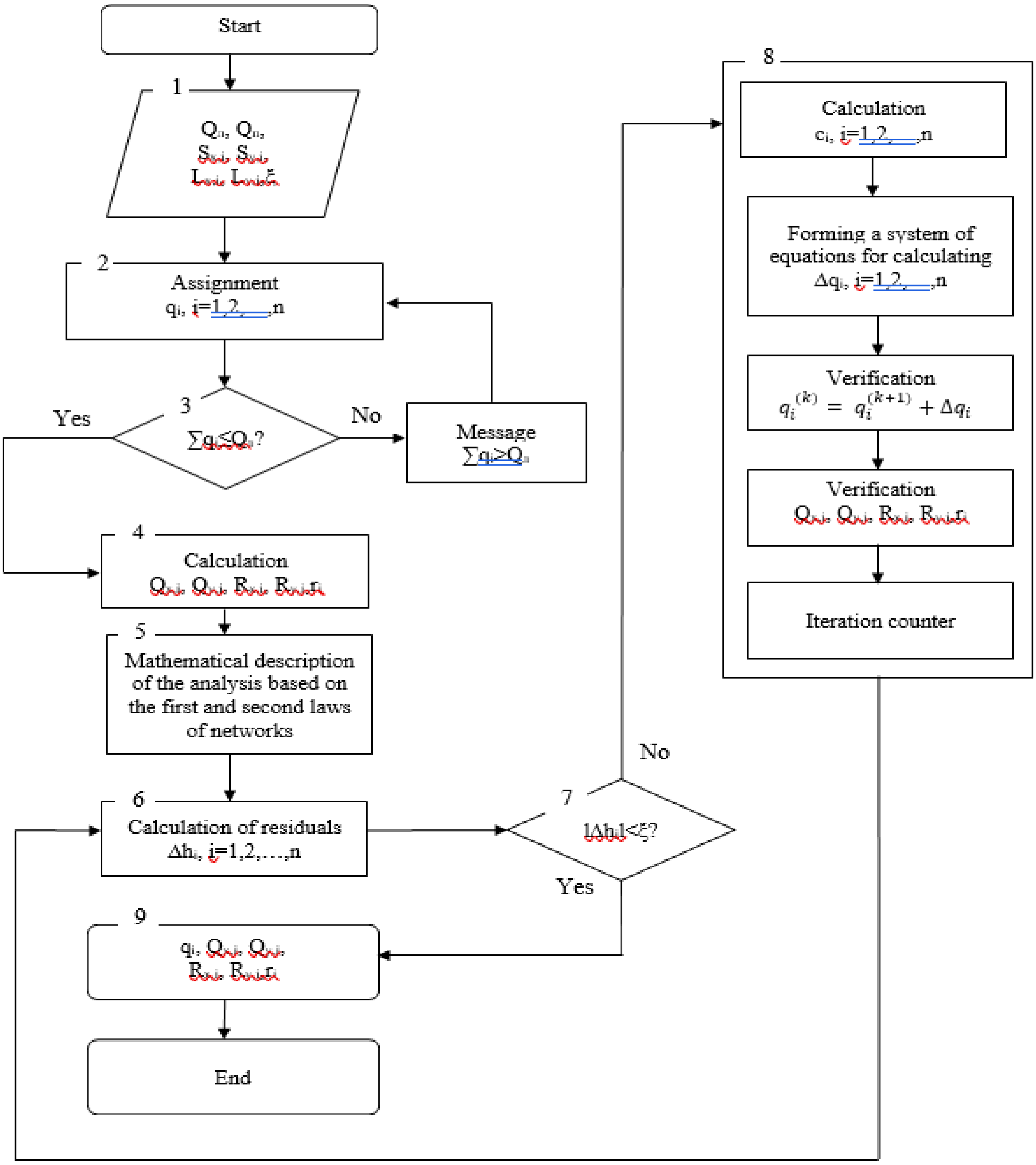

Figure 3 – Procedure of determining air losses

Increasing the amount of air to ventilate the longwall and decreasing the amount of air for fresh into the ventilation working to the ratio of 1.5 ensured further normalization of the ventilation mode of the breakage face and the potentially dangerous section of the longwall with the ventilation working and bringing it into line with the established norms and industrial safety requirements.

As the coal seam is mined and the line of the stope advances, the immediate and main roof of the seam collapses in the mined-out area of the longwall. The process of collapse of the seam roof rocks entails increasing rock pressure on the supported ventilation working, which ultimately leads to decreasing the cross-sectional area of the working, soil heaving and deformation of the lining elements.

The second way to control gas release in the extraction area is aimed at reducing aerodynamic resistance of the supported ventilation opening by increasing the cross-sectional area. When using this method of controlling gas release, the swollen soil of the supported ventilation working is blasted (removed) with the replacement of deformed elements of the arched metal support at the distance of up to 1000 meters from the junction with the stope. As a result of demolition, air leaks increase through the collapsed coal rock massif of the mined-out area, which decreases the amount of air passing through the longwall and deteriorates ventilation in the area where the longwall mates with the ventilation working.

The negative effect of undermining on the ventilation of the area as a whole also takes place when it is used in combination with changing the air supply to the longwall and additional air supply to the supported ventilation working, as well as with partial isolation of the goaf. However, soil undermining is necessary to solve technological problems and it should be taken into account in the analysis process to obtain objective data of the air distribution in the excavation area.

When using the third method of controlling gas release, work was carried out to reduce the filtration properties of the mined-out area of the longwall by isolating the sides of the supported ventilation working at the distance of up to 200 meters from the stope using binders. The specified method of gas emission control allows increasing the amount of air involved in the ventilation of the bottomhole part of the stope working and reducing the total amount of air leakage through the collapsed coal rock massif of the mined-out area of the longwall. Basically, air leaks in the zone of isolation of the ventilation working are reduced. In other directions, air leaks are redistributed with their slight increasing.

As a result of using the third method of gas emission control, stable ventilation of the potentially dangerous section of the longwall junction with the ventilation working is achieved and the risk of gassing the workings of the excavation section is eliminated with a direct-flow ventilation scheme.

Results and discussion

Based on the analysis of the experimental results, there can be concluded the following.

Undermining a supported ventilation opening to increase the cross-sectional area cannot be recommended as an effective way to control gas release in an excavation area. As a result of undermining the ventilation working, air leakage through the coal-rock massif of the goaf increases and the amount of air for ventilation of the working face decreases, which negatively affects the ventilation mode of the area where the longwall meets the ventilation working. It is possible to recommend changing the ratio of the amount of air supplied to ventilate the working face and the amount of air supplied to illuminate the outgoing air stream from the longwall as an effective way to control the gas release of the extraction area.

An efficient way to control the gas release of the excavation area is isolation of the mined-out area of the longwall from the side of the supported ventilation opening.

The use in combination of all the above methods of controlling the gas release of the excavation area also did not lead to an improvement in the ventilation mode of the unstable ventilation zone. Thus, undermining the soil of a supported ventilation working cannot be used as a way to improve the ventilation of an excavation area, but can only be used to solve any technological problems.

Conclusions

In this paper, it is proposed to use the developed quasi-network model of an excavation area with a straight-through ventilation scheme and an algorithm for calculating air leaks from the breakage face into a supported ventilation working to select the most effective ventilation modes and to control methods of gas release in the excavation area.

The calculation algorithm makes it possible to predict the air and gas situation in the existing workings of the excavation area with a straight-through ventilation scheme using various methods of gas release control.

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