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REDUCING EXTERNAL AIR LEAKAGE AT THE MAIN VENTILATION UNIT OF THE MINE

Purpose. To increase the efficiency of mine ventilation by reducing external leaks through the ventilation shaft construction. To achieve this goal, it is necessary to solve the following tasks:
- to analyse the existing methods for reducing external leaks through the ventilation shaft components;
- consider the possibility of using a counteracting fan to unload the main fan from external leaks;
- to establish the mutual influence of the main and counteracting fans during their joint operation;
- to develop a methodology for determining the operating mode of the auxiliary fan in which external leaks are stopped in full.

Methodology. To accomplish the set tasks, the analysis of the existing methods for combating external leaks in the main fan of the mine was carried out; a mathematical model was developed for controlling the ventilation modes of the main and auxiliary fans during their joint operation. Based on the mathematical model, the degree of mutual influence of the fans on each other was studied, a technique was developed for determining their mode, in which the mine jet in full volume enters the main fan, and external leaks are stopped by the auxiliary fan.

Findings. A mathematical model for controlling mine ventilation and stopping external leaks in the ventilation shaft elements has been developed using the methods for planning industrial experiments; the degree of mutual influence of the fans on each other has been established; a method has been developed for determining the mode of their joint operation, in which the main fan is not loaded with external leaks.

Originality. The degree of mutual influence of the main and auxiliary fans during their joint operation has been determined. The conditions are studied under which the mine jet enters the main fan, while external leaks occur to the auxiliary fan.

Practical value. The studies conducted make it possible to separate external leaks from the main stream coming out from the mine, which increases the safety of work and reduces the cost of ventilating the mine.

Key words: *mine, main ventilation unit, external leaks, counteracting fan*

Introduction. Modern mining enterprises feature high production capacity and an increasing depth of mining. This, in turn, causes an increase in the consumption of fresh air for ventilation of mining operations and makes it necessary to increase the productivity of the main ventilation units (MVU) (Q_m) and their depression.

Due to the increasing depression of the mine under the suction method of ventilation and insufficient tightness of the surface complexes of the ventilation shafts, there is an increase in air leaks through the gaps in the structure of the mine building (external leaks) (Q_{el}), These leaks reach 30 % of the flow rate of the main ventilation fan (Q_f); since in this case $Q_f = Q_m + Q_{el}$, this leads to a decreasing air flow into the mine (Fig. 1).

To normalize the air flow into underground mine workings, the ventilation mode of the mine is intensified, that is, when calculating the required flow rate of the MVU, a correction factor for external leaks is introduced. This results in an increase in the cost of electricity for mine ventilation.

Thus, the reduction of external leaks is one of the main directions in the complex of measures to improve the efficiency of underground mining ventilation. Therefore, research into reducing air leakage through the surface construction of the main ventilation unit is an urgent task.

Literature review. External leaks are determined by the difference between the flow rate of the main ventilation unit and the amount of air coming from the mine. The mode of air flow during suctioning can be turbulent (in large cracks and crevices) or laminar (during filtration). Thus, with suction, a quadratic, linear or intermediate resistance law $h = RQ^n$ $(1 < n < 2)$ is possible. To calculate the amount of air leakage, it is necessary to know the values of *h, R*, and *n*, which are sometimes impossible to determine. Therefore, application of existing analytical and special methods for calculating ventilation networks (linearization, successive approximations, minimization of special functions, graph theory) to calculate external leaks causes certain difficulties [1].

According to the results of a survey of the ventilation systems of mines, it was found that only a third of the mines have external air leaks which do not exceed 20 % of the flow rate of the draft source, while in other mines, they reach 20–50 % [2, 3].

When designing a mine ventilation system, the choice of the main ventilation unit should be made taking into account external leaks. According to [4], its supply Q_f (m^3/s) is deter-

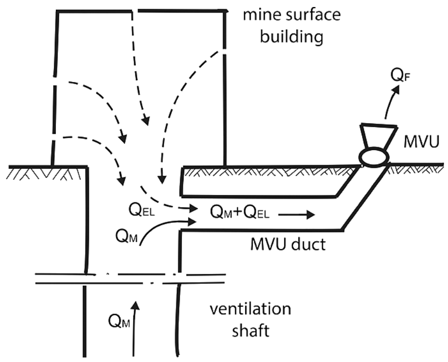

Fig. 1. Scheme of the main ventilation unit when there are external leaks:

Q_f – MVU flow rate, m^3/s; Q_{el} – external leaks, m^3/s; Q_m – outgoing ventilation jet of the mine, m^3/s

mined by the formula $Q_f = Q_m C_{el}$, where C_{el} is the coefficient which takes into account air leakage through the mine surface structures, which is taken to be equal to: 1.25 – when installing a fan on a skip shaft; 1.2 – on the cage shaft; 1.1 – on shafts and pits which are not used for lifting; 1.3 – on the pits used for lifting and lowering materials. Such large air losses due to external leaks are explained by the imperfection of the sealing elements of the structures of mine surface buildings. During their construction, foundations, walls, ceilings, windows, doors and gates, copra sheathing interfaces with ceilings, walls and foundations, heap sheathing, a valve for the passage of a lifting pit, receiving bunkers for coal and rock, and others are subject to sealing [4, 5].

Apart from sealing the mine surface building, a number of technical devices have been proposed to reduce the cost of its reconstruction. In [6, 7], to reduce external leaks, it is proposed to use an air curtain which changes the structure of air flows at the mouth of the ventilation shaft. As a result, at the site of the air curtain, the aerodynamic resistance of the shaft mouth increases from reference level to the junction with the fan drift and the depression in the mine surface building decreases, which helps to reduce the magnitude of external leaks. The disadvantage of the proposed technique, in our opinion, is the difficulty of regulating the parameters of the air curtain and, as a rule, the need to install a separate compressor unit for these purposes.

Unsolved aspects of the problem. To reduce leakages through the mine surface building, we propose the installation of a special low-power counteracting fan. It is installed near the mine surface construction of the ventilation shaft, which serves to discharge air from underground workings, and is designed to remove those air masses from the mine surface building which flow into it through gaps in the elements of the mine surface building and form parasitic inleakage which loads the main ventilation fan. In this case, it is assumed that the entire volume of air from external leaks, or part of it, does not enter the main fan, and, thus, the efficiency of underground mining ventilation increases. Therefore, two ventilation units are installed on the shaft, which are switched on for parallel operation (Fig. 2).

Here, Q_1 is the main ventilation fan flow rate, m^3/s; Q_2 is counteracting fan flow rate, m^3/s; Q_m is air flow in the mine ventilation network, m^3/s; Q_{el} is external leaks through a mine surface construction, m^3/s.

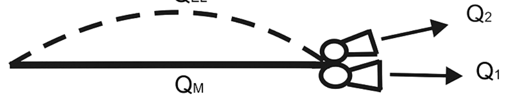

Fig. 2. Fan switching circuit

The counteracting fan is installed in those mines where air leakage through the mine surface buildings exceeds the normalized value (up to 20 % of the mine flow rate). In addition, it is advisable to use a counteracting fan in cases when external air leaks are within acceptable limits; however, it is necessary to increase the supply of fresh air in underground workings in order to provide a sufficient amount of air by dust and gas factors for mining operations. In this case, the use of a counteracting fan may be more cost-effective than the reconstruction of the MVU or other measures to increase the air supply to the mine.

To date, no theoretical or practical studies have been conducted on the mutual influence of the main fan and counteracting one on each other. Moreover, methods have not been developed for determining the operating mode of the counteracting fan, in which the flow rate of the main fan is equal to the calculated amount of air for of underground mining ventilation, and the flow rate of the counteracting fan is equal to external leaks through the mine surface building. The present work is devoted to the solution of these issues.

Theoretical studies. Depending on the ratio of the pressure difference developed by the fans, three modes of their joint operation are possible (Fig. 3).

Mode a – external leaks Q_{el} are removed from the mine surface building in full by the counteracting fan, and the air Q_m coming from the mine network enters the main fan. In this case, the flow rate of the counteracting fan is equal to external

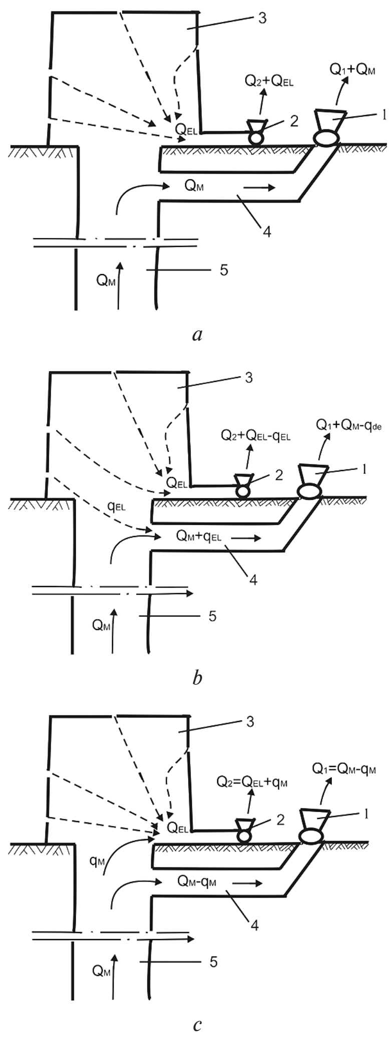

Fig. 3. Operating modes of the counteracting fan to prevent external air leaks:

1 – main fan; 2 – counteracting fan; 3 – mine surface building; 4 – main ventilation unit duct; 5 – ventilation shaft

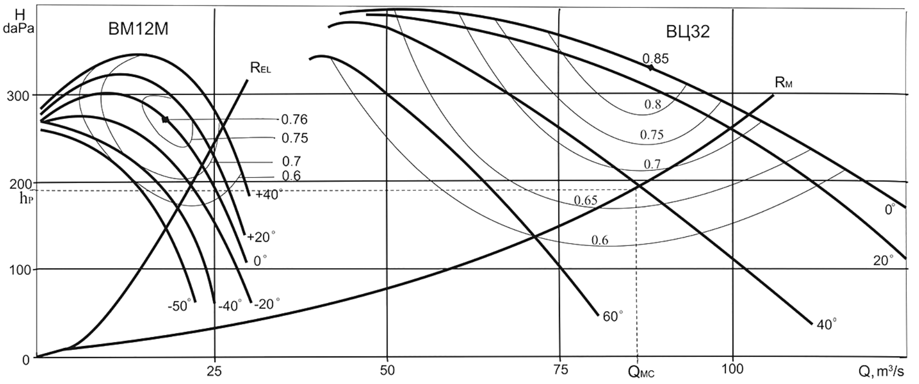

Fig. 4. Aerodynamic characteristics of ВЦ32 and BM12M fans, mine ventilation network and ways of air suction through leaks of the mine surface building

leaks $Q_2 = Q_{el}$, while the flow rate of the main fan $Q_1 = Q_m$. Such a distribution is possible when the static pressure at the shaft mouth is equal to the static pressure at the mouth of the main fan duct.

Mode b – part of the external leaks q_{el} enters the main fan. In this case, $Q_2 = Q_{el} - q_{el}$, while $Q_1 = Q_m + q_{el}$. Thus, the main fan is loaded with additional air volumes q_{el} which do not participate in the underground mining ventilation, but, on the contrary, reduce the flow of fresh air into the mine. In this case, the static pressure at the shaft mouth is higher than at the mouth of the main fan duct.

Mode c – part of the mine jet q_m through the ventilation shaft mouth enters the counteracting fan, that is, $Q_2 = Q_{el} + q_m$, while $Q_1 = Q_m - q_m$. In this case, part of the jet enters the building, which leads to a deterioration in sanitary and hygienic conditions and the safety of people working here. Such a distribution is observed when the pressure at the mouth of the main fan duct is higher than at the shaft mouth.

In this paper, the task was set to develop a method for determining the mode of joint operation of fans, in which external leaks will be taken by the counteracting fan, while the jet coming from the mine – by the main fan. Moreover, studies are required on their mutual influence on each other when working together.

Due to the lack of the possibility of conducting research on a full-scale object, a mathematical model of a mine ventilation system was developed, whose main ventilation unit is equipped with ВЦ 32 fans (centrifugal fans), and a BM12M fan was installed in the mine surface building to remove external leaks. Fig. 4 shows their combined aerodynamic characteristics [3, 8].

The aerodynamic characteristic of the ВЦ32 fan is represented by a family of curves which express the functional relationship between the pressure difference developed by it (H, daPa) and air supply (Q, m^3/s) at various resistances of the mine ventilation network R_m. The flow rate of the fan is controlled by an axial guide vane whose blade angles can be changed from 0 to 60 degrees.

The aerodynamic characteristic of the BM12M fan is a family of curves which describe the relationship between its depression (H, daPa) and flow rate (Q, m^3/s) at various values of the aerodynamic resistance of external leaks R_{el}. The flow rate of the fan is controlled by an axial guide vane, whose blade angles can be changed from +40 to –50 degrees.

The aerodynamic characteristic of the mine ventilation network in the analytical expression is of the form $H_m = R_m Q_m^2$. In Fig. 4, this characteristic is presented graphically and is designated as R_m. The aerodynamic characteristic of external leaks in the mine surface building in an analytical expression has the form $H_{el} = R_{el} Q_{el}^2$. In Fig. 4, this characteristic is presented in a graphical form and is designated as R_{el}.

Let us take the calculated amount of air for mine ventilation as $Q_{mc} = 85$ m^3/s. At the same time, the calculated operation mode of the main fan is in the zone of its industrial use, that is, with efficiency over 0.6. Its closest individual aerodynamic characteristic, under which the condition $Q_1 \geq Q_{mc}$ is met, is a characteristic with a blade angle of the guide vane being 40°.

All these dependencies, which are shown in graphical form in Fig. 4, represent a mathematical model of the mine ventilation system in which a counteracting fan is used to remove external leaks.

It should be noted that under real conditions of an operating mine, the ventilation mode is influenced by variable natural draft.

The depression of natural draft in winter is usually positive, since it acts co-directionally with the depression of the main fan as a result of the fact that the air supplied to the mine has a temperature lower than that released from it. In the summer period, the opposite is observed, while the natural draft interferes with work of the main fan. In the autumn-spring period, the temperatures of the incoming and outgoing jets are often equal, which results in a ventilation mode with zero natural draft.

To simplify graphical processing, a zero value for this draft is taken in our studies.

When solving the problems posed in the work, we applied the methods for planning industrial experiments [9]. These methods consider the object under study as a cybernetic system with input and output parameters (Fig. 5).

The input parameters of the system under study are the blade angle of the guide vane of the main fan θ_1 and the blade angle of the guide vane of the counteracting fan θ_2. They meet the requirements for the input parameters of the system; namely, they:

- control the operation mode of the object under study;
- are easy to install and measure;
- do not depend on each other and have no correlation;
- can be in the established position as long as it takes;
- any combination of their values does not result in emergencies.

The output parameters of the system under study are:

- Q_1 – flow rate of the main fan, m^3/s;
- Q_m – air flow in the ventilation shaft, m^3/s;

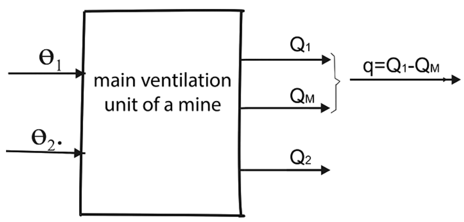

Fig. 5. Schematic diagram of the mine ventilation system as a control object

Table 1

Characteristics of the input parameters

Type of value representation	The main fan				The counteracting fan			
	Θ_{1max}	Θ_{1min}	Θ_{10}	$\Delta\Theta_1$	Θ_{2max}	Θ_{2min}	Θ_{20}	$\Delta\Theta_2$
Natural, degrees	60	0	30	±30	+40	–50	–5	±45
Coded	+1	–1	0	±1	+1	–1	0	±1

- Q_2 – flow rate of the counteracting fan, m^3/s;
- $q = Q_v - Q_1$ – difference between the outgoing mine ventilation jet and the flow rate of the main fan.

The methods of the theory of industrial experiment, which are based on the results of a properly planned change in the input parameters and measurements of the values of the output parameters at the same time, make it possible to determine the analytical dependences of the output parameters on the values of the input parameters [11]. An experiment of this kind is called active and can be planned.

The most common method is that of planning at two levels of change in input parameters [10, 11]. In this case, the values of the input parameters are set in the experiment, which correspond to the upper and lower limits of their regulation range, that is, they cover the entire zone of industrial use of fans. They are called the upper and lower levels and are denoted by +1 or –1, respectively, whereas their change from the average value Θ_{10}, Θ_{20} (zero level) is a step of varying the input parameters $\Delta\Theta_1$, $\Delta\Theta_2$. Table 1 shows the characteristics of the input parameters of the system under study.

Experimental designs in which the input parameters change at two levels are called 2^K type designs, where K is the number of input parameters. If you change the origin of reading of the input parameter values (transfer it to the zero-level point) and the scale of the axes from natural values (Θ_1, Θ_2) into variation steps $(\overline{\theta}_1, \overline{\theta}_2)$, , then the plan of the experiment can be represented as a matrix. In the new coordinate system, the values of the input parameters of the conducted experiments correspond to the coordinates of the rectangle, which has the centre at a point with zero levels of input parameters, and the sides have a length of two steps of varying the corresponding parameter (Table 2).

Table 2

Plan of the experiment

Trial number	Natural values, degrees		Coded values	
	Θ_1	Θ_2	$\overline{\theta}_1$	$\overline{\theta}_2$
1	60	40	+1	+1
2	0	40	–1	+1
3	60	–50	+1	–1
4	0	–50	–1	–1

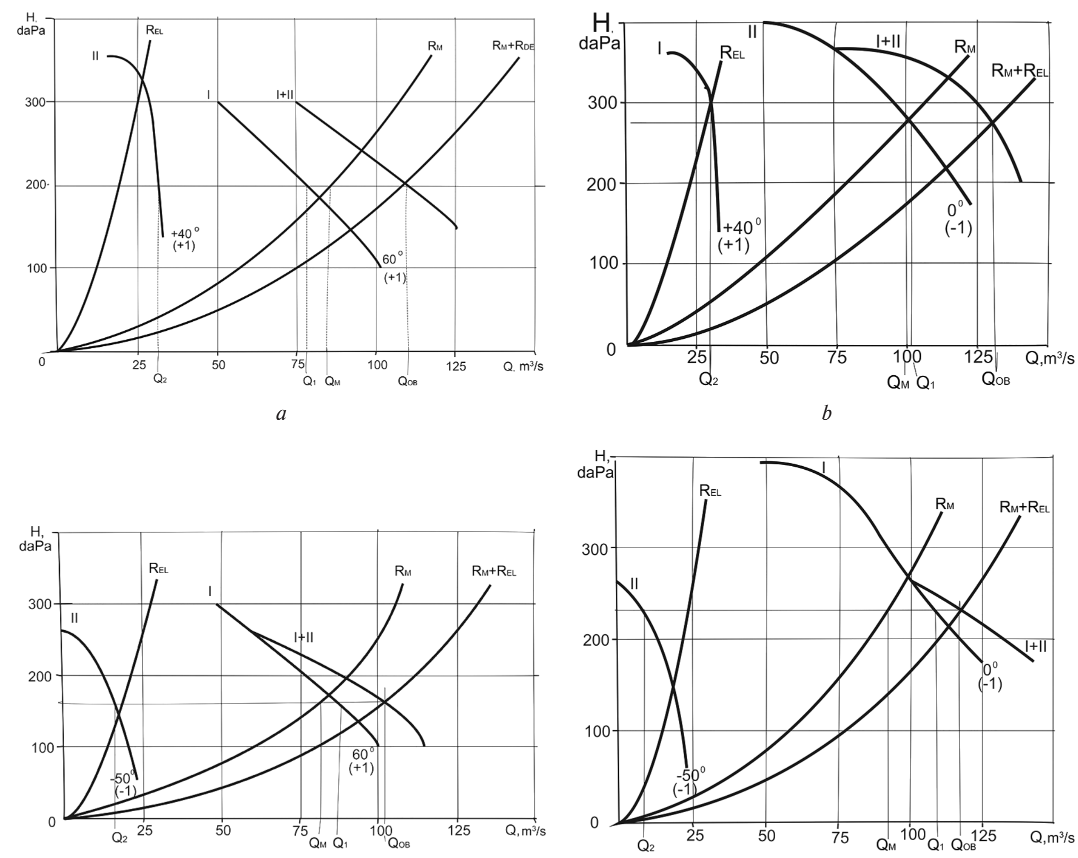

Fig. 6. Determining the output parameters of the system during the experiment:

a – trial No. 1 with the values of input parameters $\theta_1 = 60$; $\theta_2 = 40$; b – trial No. 2 with the values of input parameters $\theta_1 = 0$; $\theta_2 = 40$; c – trial No. 3 with the values of input parameters $\theta_1 = 60$; $\theta_2 = -50$; d – trial No. 4 with the values of input parameters $\theta_1 = 0$; $\theta_2 = -50$

Table 3

Values of the output parameters

Trial number	Q_1, m^3/s	Q_m, m^3/s	Q_2, m^3/s	$q = Q_m - Q_1$ m^3/s
1	78	80	32	–2
2	102	100	30	2
3	86	82	16	4
4	109	93	9	16

The experiment is conducted based on the mathematical model in a graphical form and in each trial, the values of the output parameters are determined (Fig. 6).

In each trial from the above schedules, we determine the values of the output parameters of the ventilation system (Table 3).

The theory of planning industrial experiments makes it possible to obtain analytical dependences of each of the output parameters on the input ones $Q_1 = f_1(\Theta_1, \Theta_2)$; $Q_2 = f_2(\Theta_1, \Theta_2)$; $q = f_3(\Theta_1, \Theta_2)$ as polynomials

$$Q_1(Q_2, q) = b_0 + b_1\Theta_1 + b_2\Theta_2 + b_{12}\Theta_1,\Theta_2, \quad (1)$$

where b_0 is an absolute term of equations; b_1, b_2 are coefficients at linear terms; b_{12} is a coefficient at the non-linear term of the equation.

To determine the numerical value of the coefficients of equation (1), the least squares method [10] is used, which features the symmetry of the matrix in the coded values of the input parameters, relative to the centre of the experiment $(\sum_{n=1}^{N} b_i = 0,$ where $n = 1.2$; N is the number of trials in the experiment) (Table 2) and to the normalization condition (the sum of the squares of the elements of each column is equal to the number of trials $\sum_{n=1}^{N} b_i^2 = N)$. Due to these, the method is reduced to simple arithmetic operations – assigning of the signs of the corresponding factor or effect of interaction to a column of the output parameter values and algebraic addition of the obtained values. Dividing the results by the number of trials in the planning matrix gives the desired coefficient. The absolute term of equation (1) is equal to the average value of the output parameter.

Let us conduct a study to determine the mode of joint operation of the main and counteracting fans, in which external leaks through the mine surface building are completely removed by the counteracting fan, and the flow rate of the main fan is equal to the volume of air coming from the mine, i. e. $Q_1 = Q_m$. In this case, the desired dependence (1) will take the form [11]

$$q = b_0 + b_1\Theta_1 + b_2\Theta_2 + b_{12}\Theta_1,\Theta_2. \quad (2)$$

Table 4 presents the results of determining the coefficients of expression (2).

Thus, expression (2) in the encoded values of the input parameters will take the form

Table 4

Determining the coefficients of expression (2)

Trial number	b_0	b_1	b_2	b_{12}
1	+(–2)	+(–2)	+(–2)	+(–2)
2	+2	–2	+2	–2
3	+4	+4	–4	–4
4	+16	–16	–16	+16
$\sum$	20	–16	–20	+8
$\sum/4$	5	–4	–5	+2

$$q = 5 - 4\bar{\theta}_1 - 5\bar{\theta}_2 + 2\bar{\theta}_1\bar{\theta}_2. \quad (3)$$

To represent expression (3) in natural values of the input parameters, it is necessary to use the conversion formulas

$$\bar{\theta}_1 = \frac{\theta_1 - \theta_{10}}{\Delta\theta_1}; \quad \bar{\theta}_2 = \frac{\theta_2 - \theta_{20}}{\Delta\theta_2}. \quad (4)$$

After calculations, expression (3) in natural values of the input parameters will take the following form

$$q = 8.223 - 0.126\Theta_1 - 0.155\Theta_2 + 0.00148\Theta_1\Theta_2. \quad (5)$$

The results of calculations to identify the error in describing the real process of controlling the mine ventilation modes applying the obtained expression (5) are summarized in Table 5.

Thus, the resulting analytical expression describes the actual ventilation modes with an error not exceeding 3.3 %. This leads to the conclusion that expression (5) adequately reflects the real process of controlling the mine ventilation modes through changing the blade angles of the fan guide vanes.

To determine the optimal operation of the fans, we proceed as follows:

- we equate the right side of expression (5) to zero

$$8.223 - 0.126\Theta_1 - 0.155\Theta_2 + 0.00148\Theta_1\Theta_2 = 0. \quad (6)$$

This expression determines the relationship between the values of the angles of the guide vanes, at which the outgoing mine ventilation jet Q_m will be equal to the flow rate of the main fan Q_1, and, therefore, the external leaks Q_{el} will be fully supplied to the counteracting fan, that is, $Q_2 = Q_{el}$;

- we substitute the value $\Theta_1 = 40$ degrees in expression (6); at this value the outgoing mine ventilation jet is equal to the calculated volume of air for underground mine ventilation $Q_m = Q_{mc}$. Then we calculate the desired value Θ_2, which will be equal to 33 degrees.

The conducted studies allowed us to establish that the desired optimal mode of joint operation of the main and counteracting fans, with which $Q_1 = Q_{mc}$, and $Q_2 = Q_{el}$, will be viable at the blade angles of the fan guide vane being 40 and 33 degrees, respectively. At the same time, when calculating the supply of the main fan, we can consider the value of the coefficient which takes into account air leakage through the surface structures as equal to one. That is, it is not required to transfer the operation of the main fan to a more intensive mode to remove external leaks, which reduces the cost of mine ventilation, improves sanitary and hygienic conditions and safety at workplaces in the mine surface building.

The second task of the research is to evaluate the mutual influence of the main and counteracting fans during their joint operation within the integrated ventilation network. For this purpose, in accordance with the above methodology based on the data in Table 3, an analytical expression was obtained which determines the flow rate of the counteracting fan Q_2 depending on the values of input adjustable parameters (guide vane blade angles Θ_1, Θ_2). It features the following form

$$Q_2 = 20.666 + 0.0703\Theta_1 + 0.233\Theta_2 - 0.000924\Theta_1\Theta_2. \quad (7)$$

Table 5

Calculation error for mine ventilation modes

Trial number	Input parameters		According to the graphs in Fig. 6	According to (5)	Error, %
	Θ_1, degrees	Θ_2, degrees			
1	60	40	–2	–1.985	1.5
2	0	40	2	2.023	3.3
3	60	–50	4	3.973	2.7
4	0	–50	16	15.973	2.7

Dependence (7) is studied as follows. We will alternately set the value of Θ_2 to all possible values (–50, –40, –20, 0, 20, 40) and in each case we calculate Q_2 with the values $\Theta_1 = 0$; 20; 40; 60.

The calculation results are presented in Table 6.

As a result of the studies, it was found that a more powerful main fan significantly influences the operation mode of a low-power counteracting one. Thus, with the lowest intensity of counteracting fan operation, its flow rate can change by 43 % only due to the regulation of the operation mode of the main fan.

Similarly, the influence of the counteracting fan on the operating modes of the main fan is established. The resulting analytical dependence of the flow rate of the main fan on the values of the input parameters of the system under study is of the form

$$Q_1 = 105.87 - 0.392\Theta_1 - 0.0775\Theta_2 - 0.000185\Theta_1\Theta_2. \quad (8)$$

Let us determine the effect of the counteracting fan on the main fan in the extreme modes of their operation. The calculation results are presented in Table 7.

Fig. 7 visualises the results of calculations of the dependence of the counteracting fan flow rate on the operating modes of the main fan.

The dependence is visualised in Fig. 8.

Table 6

The results of the study on the influence of the main fan on the counteracting fan operating mode

No.	Θ_2, degrees	Θ_1, degrees				Changes in Q_2	
		0	20	40	60	m^3/s	%
1	–50	9.0	11.35	13.68	16.0	7.0	43.0
2	–40	11.35	13.49	15.64	17.78	6.4	35.0
3	–20	16.0	17.78	19.56	21.33	5.3	24.8
4	0	20.70	22.0	23.48	24.88	4.2	17.0
5	20	25.33	26.36	27.40	28.44	3.1	10.9
6	40	29.99	30.65	31.32	31.99	2.0	6.2

Table 7

The results of the study on the influence of the counteracting fan on the main fan operation mode

No.	Θ_1, degrees	Θ_2, degrees		Changes in Q_1	
		40	–50	m^3/s	%
1	60	77.4	86.8	9.4	10.8
2	0	102.8	109.8	7.0	6.4

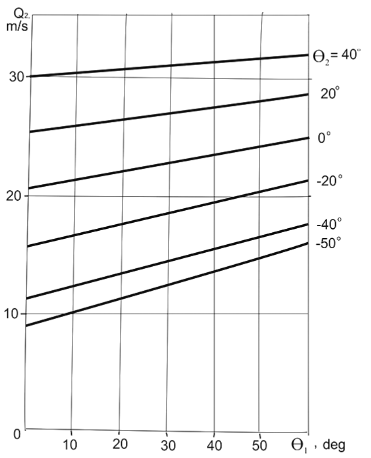

Fig. 7. Counteracting fan operation modes with the operation mode of the main fan regulated

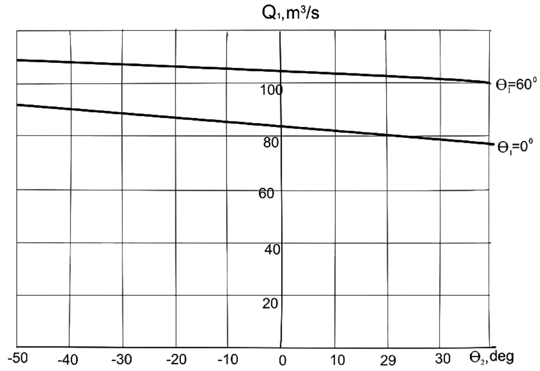

Fig. 8. Main fan operating modes of the with the operating mode of the counteracting fan regulated

Thus, it is found that the counter fan has less influence on the main fan. Thus, only by adjusting the operating mode of the counteracting fan, the flow rate of the main fan of the studied ventilation system can be changed up to 10.8 %.

Conclusions. As a result of the studies:

- a method has been developed to determine the optimal operation of the counteracting fan to reduce external leaks in the mine surface construction of the air shaft;
- approbation of the proposed method was carried out based on a mathematical model of the mine ventilation system, whose ventilation shaft is equipped with a counteracting fan;
- optimal fan operation modes are set, in which external leaks are removed by the counteracting fan, and the air flow returning from the shaft enters the main fan;
- the degree of influence of the main fan on the operating mode of the counteracting fan was studied;
- it has been established that the flow rate of the counteracting fan can change up to 43 % only due to adjusting the operating mode of the main fan;
- the degree of influence of the counteracting fan on the mode of operation of the main fan was studied;
- it has been established that the flow rate of the main fan can change up to 10.8 % only by adjusting the operating mode of the counteracting fan.

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Зниження зовнішніх витоків повітря на головній вентиляційній установці шахти

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Мета. Підвищення ефективності провітрювання шахти за рахунок зменшення зовнішніх витоків через конструкції вентиляційного стовбура. Для досягнення поставленої мети необхідно вирішити такі завдання:

- провести аналіз існуючих методів зниження зовнішніх витоків через конструкції вентиляційного стовбура;
- розглянути можливість застосування протидіючого вентилятора для розвантаження головного вентилятора від зовнішніх витоків;
- встановити взаємний вплив головного та протидіючого вентиляторів при їх спільній роботі;
- розробити методику визначення режиму роботи допоміжного вентилятора, за якої зовнішні витоки видаляються в повному обсязі.

Методика. Для виконання поставлених завдань у роботі проведено аналіз існуючих методів боротьби із зовнішніми витоками на головній вентиляційній установці шахти, розроблена математична модель управління вентиляційними режимами головного й допоміжного вентиляторів при їх спільній роботі. На математичній моделі досліджені ступінь взаємного впливу вентиляторів один на одного, розроблена методика визначення їх режиму, при якому струмінь, що виходить із шахти, у повному обсязі надходить на головний вентилятор, а зовнішні витоки видаляються допоміжним вентилятором.

Результати. Розроблена із застосуванням методів планування промислових експериментів математична модель управління провітрюванням шахти й видалення зовнішніх витоків у конструкції вентиляційного стовбура, встановлено ступінь взаємного впливу вентиляторів один на одного, розроблена методика визначення режиму спільної роботи вентиляторів, за якої головний вентилятор не навантажується зовнішніми витоками.

Наукова новизна. Встановлено ступінь взаємного впливу головного й допоміжного вентиляторів при їх спільній роботі. Досліджені умови, при яких вихідний струмінь із шахти надходить на головний вентилятор, а зовнішні витоки – на допоміжний.

Практична значимість. Проведені дослідження дозволяють відокремити зовнішні витоки від основного струменя, який виходить із шахти, що дозволяє підвищити безпеку робіт і знизити витрати на провітрювання шахти.

Ключові слова: *шахта, головна вентиляційна установка, зовнішні витоки, протидіючий вентилятор*

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