DOI 10.52209/1609-1825_2022_2_302 UDC 697.98

Ways of Energy Saving in Ventilation Systems of Coal Mines

[1]***MAKHMUTOVA Sabina,** *master, doctoral student, 777sabin777@mail.ru,*
[1]**KALININ Alexey,** *PhD, Head of Department, a.kalinin@kstu.kz,*
[2]**BOTH Reinhold,** *PhD, Director, reinhold.both@cft-gmbh.de,*
[3]**MARIUS Heller,** *PhD, Engineer, geller@fh-dortmund.de,*
[1]*NPJSC «Abylkas Saginov Karaganda Technical University», Kazakhstan, Karaganda, N. Nazarbayev Avenue, 56,*
[2]*CFT GmbH, Germany, Gladbeck, Beisenstraße, 39-41,*
[3]*Korfmann, Germany, Gladbeck, Beisenstraße, 39-42,*
**corresponding author.*

Abstract. *The purpose of the article is to substantiate and improve the energy efficiency of ventilation systems of mining enterprises. Today, the topic of energy saving and energy efficiency is relevant and is considered for various enterprises and fields of activity. The article describes the possibilities of expanding the functions of automatic control systems and monitoring the operation of fans of the main ventilation of mines. This will ensure the safety of underground production, including by supplementing the energy efficiency control functions of general mine ventilation. The optimization of the operating modes of the fans of the main ventilation of mining enterprises is considered.*

Keywords: *main ventilation fans (MVF), energy saving measures (EM), mine ventilation network, energy saving, energy efficiency, general mine ventilation, mining, aerodynamic characteristics, electricity consumption.*

Introduction

One of the most important problems of labor protection at mining enterprises is the fight against gas, dust and high temperatures in underground mining. The main means of combating these hazards is the ventilation of mine workings, and its share is currently 80-90%. In this regard, the requirements for the efficiency and reliability of the operation of mine ventilation systems to create and maintain normal sanitary and hygienic working conditions are significantly increasing.

Thanks to the work of a number of scientists and research teams, the problem of improving the efficiency of mine ventilation systems has now received a reliable theoretical foundation.

However, an analysis of the actual state of ventilation systems in operating mines and mines shows that a significant number of main ventilation fans operate at low efficiency values, there is an unstable supply of the required amount of air to the mine ventilation network, and the issue of air leaks supplied to the mine network remains relevant. for ventilation [1-2].

The safety and productivity of miners largely depends on the quality and continuity of ventilation of mine workings. At the same time, the ventilation process requires a large amount of electricity.

Fan installations in coal and ore mines consume approximately 1.5% of the total amount of electricity generated, incl. fan installations in coal mines – 1%. The ventilation of each mine consumes up to 30% of all electricity consumed by it. Large energy costs are associated with high performance of fan installations, and the amount of air supplied to the mine is 3, 3.5 times more than coal is mined. The large energy consumption of ventilation units places high demands, on the one hand, on their correct operation and operation in the optimal mode, and on the other hand, on the efficiency of these machines.

Increasing their efficiency by only 1% saves many millions of kilowatt-hours of electricity and millions of tenge.

As a result of a survey of a large number of mines, it was found that air leaks range from 22.7% to 66.2% of the volume of air entering the mine.

Therefore, the issue of reducing the energy intensity of mine ventilation remains relevant, and its further study is an urgent scientific and technical task.

World trends in energy saving, as well as modern trends in the development of equipment and technology of coal production, irrefutably prove that when creating automation systems for controlling the main ventilation fans (MVF), in addition to generally accepted safety requirements, i.e., the continuous supply of underground work with the necessary amount of fresh air, it is necessary take into account the requirements of energy efficiency [3].

Main part

When improving ventilation systems in coal mines and developing the energy-saving part of the functional and technical requirements for automated control systems for main ventilation fans, it is important to consider possible energy-saving measures (EMS).

Airing is the most energy-intensive process. It consumes up to 40% of the electricity consumed by the mines. These costs can be reduced by 40-50% by implementing VEM to improve ventilation systems.

VEM for the improvement of general mine ventilation systems can be grouped into three main areas:

- improvement of the ventilation network;
- optimization of VGP operation modes;
- improvement of fan installations of the main ventilation.

Improvement of the ventilation network. VEM in this area includes:

1. Reduction of external air leaks [4] through elements of ventilation installations and mine buildings: casing of headframes, sealing devices of shaft mouths or pits; in fan ducts through leaks in vents, dampers, doors and duct walls. The volume of air leaks can reach 18-50% of the supply.

Reducing air leaks to the standard values allows saving from 0.5 to 2 million kWh of electricity per year (repairing the lining of pile drivers, sealing devices at the mouths of shafts or pits, sealing ventilation ducts, installing additional sealing devices special air valves at the mouths of ventilation shafts);

2. Improvement of the aerodynamic characteristics [5-6] of the ventilation network, i.e. reducing the aerodynamic resistance of the network, reducing the general mine depression (carrying out additional ventilation workings, using workings with a larger cross-sectional area, increasing the cross-sectional area of existing workings by reinforcing them, chamfering corners at the turns of the air jet; lining, tightening, plastering workings; reduction of local airflow resistance in workings by removing debris, removing unused equipment, trolleys, materials, etc.; reduction of the length of the network, the repayment of workings, a change in the ventilation scheme; elimination of spillage of rock mass when unloading skips to reduce dust ingress into ventilation ducts; cleaning of ventilation ducts from dust manually or using specialized equipment, other ways to improve the aerodynamic characteristics of ventilation ducts to reduce drawdown losses; the use of energy-saving types of reinforcement of mine shafts);

3. Reduction of air leaks [7-8] through underground ventilation structures: lintels, doors, locks (replacement of outdated doors and locks with more advanced doors VD-600/900 and automated lock devices USHA, which, in addition to eliminating excess air leaks, prevent «short circuit» of the ventilation stream, allow to reduce the number of methane explosions due to gassing of workings); applying a cement-polymer composition to sealing coatings of underground ventilation structures.

Leaks in underground workings through ventilation devices account for up to 37% of the air entering the mine. To compensate for them, on average, up to 25% of the electricity consumed for ventilation is consumed.

Optimization of MVF operation modes [9] consists in minimizing the cost of electricity for supplying the necessary (and sufficient to maintain safe working and working conditions) air volume to the mine. This is achieved by the development and implementation of measures in the following areas:

- coordination of operation modes of two or more MVFs operating on a common ventilation network in order to eliminate their negative impact on each other in terms of electricity consumption;
- changing the mode of operation of the MVF in case of seasonal changes in natural draft for its rational use. In winter, natural draft in mines can be 30% fan depression, and energy savings 15%;
- optimal coordination of the MVF operation mode with the current characteristics of the ventilation network, with its changes as a result of the implementation of the VEM to improve it, as well as production conditions (increase or decrease in coal production, streamlining or development of mining, etc.).

To coordinate the operation modes of the MVF with the characteristics of the ventilation network of the mine, the following is performed:

- change the frequency of rotation of the fan impeller.

Improvement of the fan installations of the main ventilation is carried out by replacing, modernizing, reconstructing and repairing them due to the wear and tear and obsolescence of the existing MVF mine stock [8].

Replacing obsolete MVFs of the first generation (VOKD 1.8; VRTsD 4.5, etc.) with new ones of the third generation (VO-18K, VTSD 37.5, etc.) saves from 0.5 to 3.85 million kW h per year, replacement of VGP electric motors up to 1.9-3.5 million kWh per year. It is advisable to replace the VGP electric drive with a voltage of 6 kV.

It is effective to use frequency regulation instead of a throttle valve or guide vane and switch to a lower speed of fans operating outside the industrial operation area with an efficiency of 45-55%. Annual energy savings can reach: 15% – for VCD 31.5M and VTS 31.5 fans, 20% – for VRTsD 4.5 and VTSD 47.5 fans (when they are switched from a rotation speed of 500 to 375 min-1); 1.6 million kWh – for the VOD-30M fan (when using the thyristor converter PCHSV6/1.5), 1-1.4 million kWh – for the VRTsD-4.5 fan (PCHSV 6/32).

Improving the condition of the flow path of the fan is a component of the improvement of fan installations. Depending on the nature of the problem to be eliminated, the operational efficiency of the fan installation can be increased by 5-10%, and in some cases by 20-40%.

The implementation of such measures as reducing the diameter of the impeller at the ends of the blades, allows for centrifugal MVF, operating with an efficiency of less than 50%, to reduce power consumption by an average of 15%.

Reducing the cost of electricity for ventilation by 20-25% contributes to the reduction in the number (thinning) of the blades of the impeller of the first or second stage.

Restoration of the guide vane, replacement of the impeller, increase in the length of the diffuser, etc. – elements of improving fan installations.

To control the operating modes of the MVF, it is important to use systems for collecting and processing information on the efficiency of electricity use. In this case, the control of the operating modes of electric drives of fan installations will save up to 15% of electricity.

The most modern technical solution for monitoring the operation of the MVF is the AKV 1000/16 equipment (TU U 33.2-04721877-001-2004), which has been mass-produced since 2004.

Back in the last century, the task of complex automation of the entire mine ventilation system was set, including the regulation of the supply of VHF when the required amount of air changed, and information and computer systems based on specialized or universal processors should have been used to collect and process information on the efficiency of electricity use.

The characteristic of the mine ventilation network is not constant, since the network is subject to changes for a number of reasons, including as a result of the implementation of the VEM, which makes it necessary to regulate the air supply to the MVF.

On many fan installations of mines, if not on the majority, MVF electric drives operate in an open cycle, i.e. without mode control when changing the parameters of the ventilation network. In such installations, only partial regulation of power consumption by aerodynamic methods of air flow control is possible: by changing the angle of installation of the impeller blades or fan guide vanes, thinning the blades, etc. use an electric drive with frequency regulation PChVS. It provides flexible regulation of the rotation speed of the fan impeller [9].

However, along with this advantage, an adjustable electric drive has a number of disadvantages that can negate the gain in electricity consumption due to the flexible regulation of the MVF. A thyristor drive requires a higher supply network power compared to an unregulated drive and additional means that increase its electromagnetic compatibility with the supply network. It is a large consumer of reactive power and a concentrated source of distortion (higher harmonics) of voltage and current, which are dangerous for capacitor reactive power compensators, as they can lead to overheating and failure.

Therefore, simultaneously with the development and implementation of a thyristor drive, it is necessary to develop and implement automatically controlled multifunctional filter-compensating devices that provide an energy-saving operation mode of the thyristor drive and a safe mode of reactive power compensators. The issues of advantages and disadvantages of a frequency-controlled electric drive are covered in more detail in articles [10]. Among the developments of foreign companies in terms of energy saving, we should mention the new FR-F700 frequency converters from MITSUBISHI ELECTRIC for use in variable-speed fan drives. For example, at a frequency of 35 Hz, this converter consumes 57% less energy than traditionally.

The existing systems of automatic control and monitoring of the operation of the VGP are designed to ensure the safety of underground production and do not have the functions of controlling the energy efficiency of general mine ventilation. They do not control external suction, internal leakage, variable drawdown losses in mine workings and ventilation ducts, changes in natural draft, plant efficiency, dynamics of absolute and specific power consumption, and other parameters of the ventilation system necessary for a comprehensive analysis of its energy efficiency. Measuring and recording flow and pressure are technological controls to ensure the safety of underground operations.

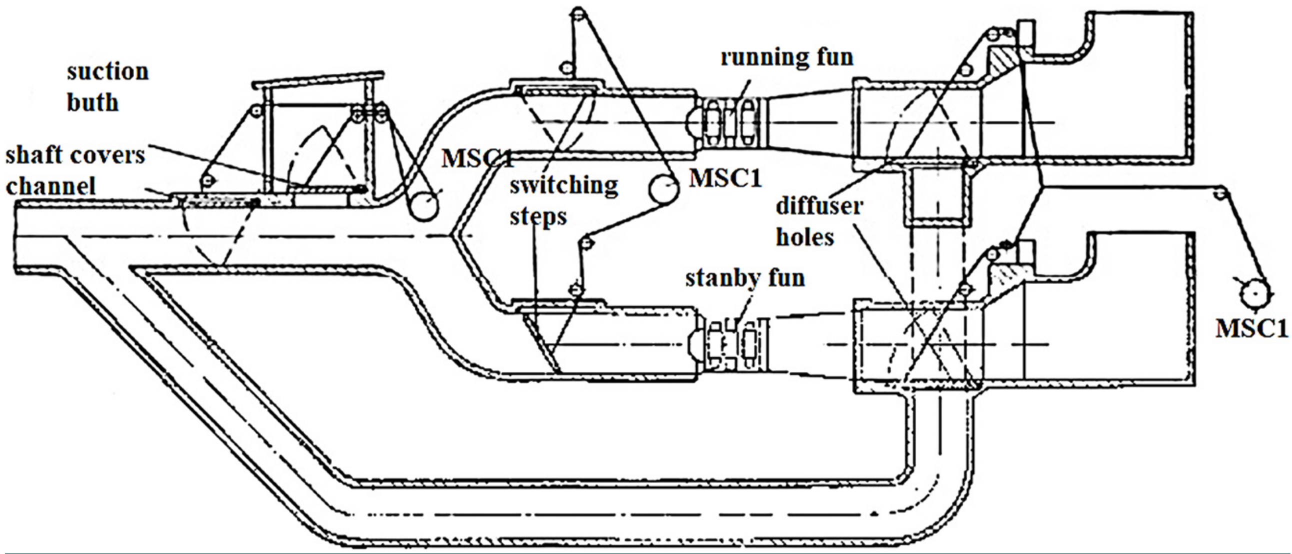
In accordance with the Rules [11], the following criteria were adopted when assessing the possibility of reducing electricity consumption for ventilation: air supply coefficients for the mine, mining areas and other consumers; the workload of each of the working VGPs; air efficiency coefficients. Ventilation ducts should be inspected at least once a month and, in case of a decrease in the cross-sectional area of the duct by more than 10%, cleaned. Drawdown losses in channels should not exceed 20%.

The mode of operation of the MVF must be stable and energy-saving. The stability of the MVF operation and the rationality of its operation modes should be checked at least once a year, as well as in case of significant changes in the ventilation network. The cost of electricity for ventilation is also reduced due to the seasonal change in the operating modes of the VGP, taking into account natural draft.

The mode of operation of the ventilation unit (figure), except for emergency cases, can only be changed on the basis of a written order from the chief engineer of the mine with notification from the head of the VTB site [12].

Thus, taking into account safety conditions, even main ventilation fan installations equipped with an adjustable electric drive actually operate in an open cycle, since the fan operation mode changes a few times during the year.

Therefore, automatic control of the operation parameters of general mine ventilation (sucks, leaks, drawdown losses, etc.) is possible only for the purpose of accumulating and processing information for its subsequent analysis, preparation and decision-making by the mine personnel on the advisability of changing the fan operation mode to a more energy



Ventilation unit

efficient one.

The need and possibility of including technical means for measuring, for example, changes in natural draft or drawdown losses in the ventilation duct, into the equipment for automatic control of the GWP, must be previously agreed with the mines-consumers of the equipment.

Conclusions

Mine ventilation is the most energy-intensive process. Main ventilation fans consume up to 40% of the electricity consumed. These costs can be reduced by 40-50%. It is necessary to create systems of a new technical level for the control and management of main ventilation fans and general mine ventilation. In addition to the generally accepted safety functions, that is, the continuity of providing underground work with the necessary amount of fresh air, they should have functions to control the energy efficiency of coal mine ventilation.

REFERENCES

1. Basisty E.Ya. Opportunities to reduce electricity consumption at the mine / E.Ya. Basisty // Energy saving. – 2002. – No. 2. – pp. 2-8.
2. Kotykhov V.N. Ways to reduce the energy intensity of mine production / V.N. Kotykhov // Energy saving. – 2001. – No. 3. – pp. 14-16.
3. V.A. Mizin, V.A. Mizin, O.V. Olkhovsky, V.A. Kostenko [et al.] Reduction of energy consumption for mine ventilation / V.A. Mizin, O.V. Olkhovsky, V.A. Kostenko [et al.] – 2008. – No. 8. – pp. 19-21.
4. Gaskevich P.A. The concept of «Energy saving» and its implementation in power supply systems of industrial enterprises / P.A. Gaskevich, A.G. Bogodisty // Energy saving. – 2001. – No. 8. – pp. 6-12.
5. Abdurmanov D. Modern equipment of industrial power supply systems // MM. Money and technology. – 2005. – No. 4. – pp. 42-47.
6. Karpov A.M. Guidelines for the design of ventilation of coal mines. – 2014. – pp. 10-15.
7. Sadchikov V.A. Methodology for calculating the parameters of ventilation of long dead-end workings of development workings, taking into account the use of modern types of VMP and various schemes for connecting air ducts. – 2008. – pp. 9-12.
8. Novikov V.Ya. Management of methane release in the mines of the Karaganda coal basin. – 2014. – pp. 5-7.
9. Energy saving. Decreasing the amount of electricity in electric power supply systems in coal mines: SOU10.1.00185790.005:2006. – Official. view. – Kyiv: Minvugleprom of Ukraine, 2006. – P. 84. – (Regulatory document of the Minvugleprom of Ukraine).
10. Kokhan P.S. Energy saving at coal mines: achievements and prospects / P.S. Kokhan // Coal of Ukraine. – 2008. – No. 8. – pp. 17-19.
11. Rules for the technical operation of coal mines: SOU 10.1–00185790–002–2005. – Official. view. – Kyiv: Minvugleprom of Ukraine, 2006. – 354 p. – (Regulatory document for the Minvugleprom of Ukraine).

Көмір шахталарының желдету жүйелеріндегі энергияны үнемдеу жолдары

[1]***МАХМУТОВА Сабина Махмутқызы,*** *магистр, докторант, 777sabin777@mail.ru,*
[1]***КАЛИНИН Алексей Анатольевич,*** *PhD, кафедра меңгерушісі, a.kalinin@kstu.kz,*
[2]***БОТ Райнхольд,*** *PhD, директор, reinhold.both@cft-gmbh.de,*
[3]***МАРИУС Геллер,*** *PhD, инженер, geller@fh-dortmund.de,*

[1]«Әбілқас Сағынов атындағы Қарағанды техникалық университеті» КеАҚ, Қазақстан, Қарағанды, Н. Назарбаев даңғылы, 56,
[2]CFT GmbH, Германия, Гладбек, Байзенштрассе, 39-41,
[3]Korfmann, Германия, Гладбек, Байзенштрассе, 39-42,
*автор-корреспондент.

Аңдатпа. *Мақаланың мақсаты – тау-кен кәсіпорындарының желдету жүйелерінің энергия тиімділігін негіздеу және жақсарту. Бүгінгі таңда энергия үнемдеу және энергия тиімділігін арттыру тақырыбы өзекті болып табылады және әртүрлі кәсіпорындар мен қызмет салаларында қарастырылады. Мақалада автоматты басқару жүйелерінің функцияларын кеңейту және шахталардың негізгі желдеткіштерінің жұмысын бақылау мүмкіндіктері сипатталған. Бұл жерасты өндірісінің қауіпсіздігін қамтамасыз етеді, оның ішінде жалпы шахталық желдетудің энергия тиімділігін бақылау функцияларын толықтыру арқылы. Тау-кен кәсіпорындарының негізгі желдеткіштерінің жұмыс режимдерін оңтайландыру қарастырылған.*

Кілт сөздер: *негізгі желдеткіш желдеткіштер (НЖЖ), энергия үнемдеу шаралары (ЭШ), шахтаның желдету желісі, энергияны үнемдеу, энергия тиімділігі, шахтаның жалпы желдетуі, тау-кен жұмыстары, аэродинамикалық сипаттамалары, электр энергиясын тұтыну.*

Способы энергосбережения в системах вентиляции угольных шахт

[1]****МАХМУТОВА Сабина Махмуткызы,*** *магистр, докторант, 777sabin777@mail.ru,*
[1]***КАЛИНИН Алексей Анатольевич,*** *PhD, зав. кафедрой, a.kalinin@kstu.kz,*
[2]***БОТ Райнхольд,*** *PhD, директор, reinhold.both@cft-gmbh.de,*
[3]***МАРИУС Геллер,*** *PhD, инженер, geller@fh-dortmund.de,*
[1]НАО «Карагандинский технический университет имени Абылкаса Сагинова», Казахстан, Караганда, пр. Н. Назарбаева, 56,
[2]CFT GmbH, Германия, Гладбек, Байзенштрассе, 39-41,
[3]Korfmann, Германия, Гладбек, Байзенштрассе, 39-42,
*автор-корреспондент.

Аннотация. *Цель статьи – обоснование и повышение энергоэффективности систем вентиляции горнодобывающих предприятий. Сегодня тема энергосбережения и энергоэффективности актуальна и рассматривается для различных предприятий и сфер деятельности. В статье описаны возможности расширения функций систем автоматического управления и контроля работы вентиляторов главного проветривания шахт. Это обеспечит безопасность подземных производств, в том числе за счет дополнения функциями контроля энергоэффективности общешахтной вентиляции. Рассматривается оптимизация режимов работы вентиляторов главного проветривания горнодобывающих предприятий.*

Ключевые слова: *вентиляторы главного проветривания (ВГП), энергосберегающие мероприятия (ЭМ), вентиляционная сеть шахты, энергосбережение, энергоэффективность, общешахтная вентиляция, добыча полезных ископаемых, аэродинамические характеристики, потребление электроэнергии.*

REFERENCES

1. Basisty E.Ya. Opportunities to reduce electricity consumption at the mine / E.Ya. Basisty // Energy saving. – 2002. – No. 2. – pp. 2-8.
2. Kotykhov V.N. Ways to reduce the energy intensity of mine production / V.N. Kotykhov // Energy saving. – 2001. – No. 3. – pp. 14-16.
3. V.A. Mizin, V.A. Mizin, O.V. Olkhovsky, V.A. Kostenko [et al.] Reduction of energy consumption for mine ventilation / V.A. Mizin, O.V. Olkhovsky, V.A. Kostenko [et al.] – 2008. – No. 8. – pp. 19-21.
4. Gaskevich P.A. The concept of «Energy saving» and its implementation in power supply systems of industrial enterprises / P.A. Gaskevich, A.G. Bogodisty // Energy saving. – 2001. – No. 8. – pp. 6-12.
5. Abdurmanov D. Modern equipment of industrial power supply systems // MM. Money and technology. – 2005. – No. 4. – pp. 42-47.
6. Karpov A.M. Guidelines for the design of ventilation of coal mines. – 2014. – pp. 10-15.
7. Sadchikov V.A. Methodology for calculating the parameters of ventilation of long dead-end workings of development workings, taking into account the use of modern types of VMP and various schemes for connecting air ducts. – 2008. – pp. 9-12.
8. Novikov V.Ya. Management of methane release in the mines of the Karaganda coal basin. – 2014. – pp. 5-7.
9. Energy saving. Decreasing the amount of electricity in electric power supply systems in coal mines: SOU10.1.00185790.005:2006. – Official. view. – Kyiv: Minvugleprom of Ukraine, 2006. – P. 84. – (Regulatory document of the Minvugleprom of Ukraine).
10. Kokhan P.S. Energy saving at coal mines: achievements and prospects / P.S. Kokhan // Coal of Ukraine. – 2008. – No. 8. – pp. 17-19.
11. Rules for the technical operation of coal mines: SOU 10.1–00185790–002–2005. – Official. view. – Kyiv: Minvugleprom of Ukraine, 2006. – 354 p. – (Regulatory document for the Minvugleprom of Ukraine).