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## Research of the influence of filter element resistance on the powered air-purifying respirator service life

**Abstract.** The purpose of the research was to determine the influence of the increasing resistance of filter elements on the service life of powered air-purifying respirators during operation in mining conditions and to substantiate the parameters of the respirator power source. The research was conducted by the computer-based simulation methods for the powered air-purifying respirator operation, which allows estimating the additional resistance of the filter caused by dust accumulation. The simulation model of the powered air-purifying respirator was developed on the basis of its physical model and, taking into account the empirical dependence of the change in the filter element resistance during dust deposition, allows determining the flow of air through the filter and the dust aerosol concentration in the working area air. The following parameters of the simulation model of a powered air-purifying respirator were substantiated: controlling action – fan rotating speed, restrictions on air flow and air pressure in the respirator mask (depending on the

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mode of working arrangements of the user), concentration of dust in the air of the working area, capacity of the power source, power consumption of the electric motor of the fan and control system components, parameters of filter elements (fibre packing density, filter layer thickness, fibre diameter, etc.), input concentration of dust aerosol, which made it possible to establish the relationship between the value of the filter element resistance and the time to complete discharge of the power source. A critical value of the resistance of the filter elements of the powered air-purifying respirator was established, which results in a significant discharge of the power source, based on the different flow rate of the air supplied to the undermask space at a given dust concentration in the working area. Relationship between the change in breathing resistance of the filters and the discharge of the power source was established, which allows determining the period of safe operation of the powered air-purifying respirator, based on the concentration of dust in the working area air and the user's working arrangement. The practical value involves determining the lifespan of the powered air-purifying respirator, based on the critical value of the filter resistance, which results in the rapid discharge of the power source

**Keywords:** controlling action; simulation model; control object; identification; research; air consumption; battery; electricity; duration of operation

## INTRODUCTION

The main function of powered respiratory protective devices (hereinafter, powered air-purifying respirators or PAPR) is to protect the user's respiratory organs from inhalation of hazardous aerosols or pathogenic microorganisms which increase the risk of occupational diseases. The efficiency of protection when using PAPR depends on comfort, degree of protection and performance. All three parameters mentioned are largely influenced by the high consumption in the air supply system and the air pressure in the undermask space of the respirator. In turn, the flow rate and air pressure determine the time of the protective action or, in other words, the service life of the PAPR, since the increase in resistance on the filters, caused by the accumulation of a dust layer on their surface, requires an increase in the performance of the fan and results in increasing energy consumption of the battery. It may be frightful to think of a situation when in a remote polluted area, where the necessary production tasks are performed, the battery suddenly discharges and the worker is left without protection. In accordance with the physical load, it is necessary to substantiate the parameters, develop and research the operation of the PAPR control system. To eliminate the negative impact on people during experimental research, it is necessary to use a simulation model of the control system of the PAPR to determine the dependence of the service life on the increasing resistance of its filter elements when used in mining conditions and to determine the parameters of the power source – the battery.

The issue of the duration of the protective effect of powered air-purifying respirators is an urgent research topic in modern science. In particular, C. Forgez *et al.* (2010) focused attention on the issues of rapid discharge of the power source of this personal protective equipment for respiratory organs. One of the factors is the increase in filter resistance, as evidenced by the research of K.T. Strickland *et al.* (2023). They found that with increasing resistance, the load on the system increases, which accelerates energy consumption. E.M. Villanueva & R. Ahmad (2021) studied the effect of frequent changes in the operating mode of the fan, which requires the rotation

frequency to be increased, which also affects the lifespan of the battery.

In order to overcome these problems, scientists propose developing new algorithms for controlling the ventilation system. A.P. Collins *et al.* (2021) suggested improved models which allow for smooth transitioning between operating modes, taking into account efficient energy consumption. This is becoming particularly important for prolonging the protective effect of respirators.

A. Licina *et al.* (2020) focused on modelling the operation modes of powered air-purifying respirators, in particular, to determine the duration of the protective action under real operating conditions. However, as noted by A. Kothakonda *et al.* (2021), maintenance of batteries when stored is also an important factor. Without proper maintenance, situations may arise when the level of protection of the respirator does not meet the requirements.

Other researchers, including Z. Xu *et al.* (2020), saw a solution in the development of algorithms for diagnosing the state of the battery taking into account external factors such as temperature and humidity. M. Bergman *et al.* (2019) make suggestions for the use of respirators with a tighter fit to the face so as to reduce air losses, which may contribute to increased service life of the device. M. Bergman *et al.* (2014) emphasise that this solution requires additional checks in production conditions to ensure proper tightness.

S.I. Cheberiachko *et al.* (2023) investigated battery types which could provide maximum lifetime with minimum maintenance costs; however, they noted that the selection of the optimal battery type depends on specific operating conditions. X. Xia *et al.* (2023) drew attention to the necessity to create simulation models which would allow accurate forecasting of energy consumption depending on device operating modes.

As a result of the analysis of the available literary sources, it was found that although the issue of the duration of the protective effect of powered air-purifying respirators is being actively studied, there is still no single agreed strategy to solve it. The purpose of the research is to substantiate the parameters of the simulated model of

the PAPR to determine the influence of the increase in the filter element resistance on the service life of the power source when used in mining conditions.

To achieve the set goal, the following tasks are to be completed:

- to develop a simulated model of a powered air-purifying respirator based on its physical model;
- to determine the critical value of the resistance of the filter elements of the PAPR which results in a significant discharge of the power source.

### MATERIALS AND METHODS

The PAPR simulation model was developed using the active experimentation method (Edirisooriya & Haas, 2023), which solved the problem of determining the structure and parameters of the mathematical model of the research object in the form of a transfer function equation. For this, a number of one-factor experiments were performed which evaluated the impact on the research object of both individual factors (change in fan rotating speed, change in filter resistance, etc.) and their interaction. Planning and processing of the results obtained during

the research were performed using formal methods of mathematical statistics.

To develop a structural diagram of a powered air-purifying respirator as an object of control and to determine the parameters of the PAPR structural elements, the main relationships were established of its constituent elements (Fig. 1), which are different in nature, namely, pneumatic ones (related to the air movement: filter, fan propeller, flexible tube with connected mask, inhalation/exhalation valves) and electrical ones (speed controller and fan motor).

To determine the structure, parameters and algorithm of operation of the air pressure regulator for the control system of the powered air-purifying respirator, a heuristic method was applied, which was based mainly on the erudition and intuition of the designer. Due to the determining of the parameters of the powered air-purifying respirator regulator, the task to increase the efficiency of its operation was solved on the basis of establishing the main relationships between the parameters.

The elements of the control and management system, according to the main characteristics of the PAPR, based on the algorithm of its work, are given in Table 1.

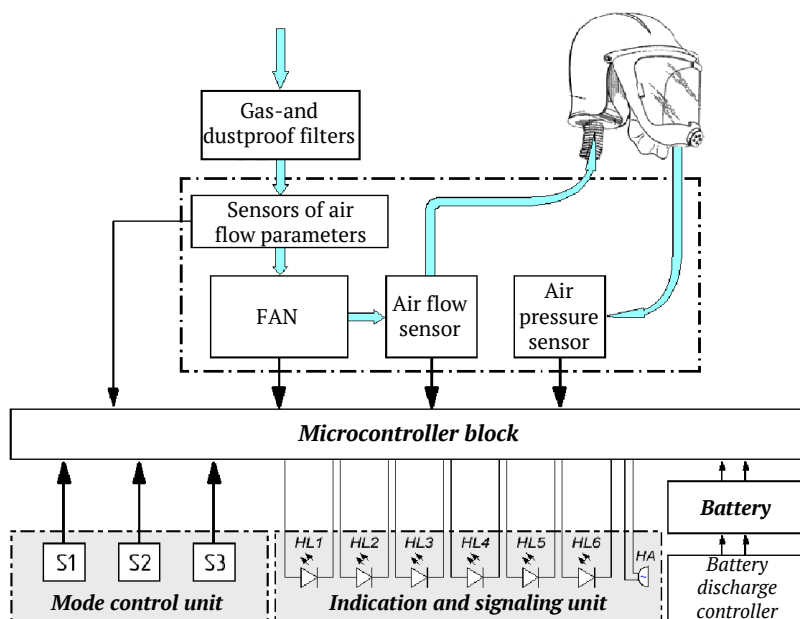
**Table 1.** Operating procedure, operation and indication sequence in different operating modes of the unit

Operations	Performed actions and running commands
Switching on	When the S1 button is pressed, the power supply voltage is supplied to the microcontroller unit, which is signalled by the HL1 LED. At the same time, the power supply voltage is supplied to the fan from the microcontroller unit (MU). After 7-10 s (the time of setting the nominal air flow rate in the air duct), the signal from the tachometer $f_t$ is sent to the MU, where it is compared with the reference frequency $f_3$ for the nominal flow rate, and if $f_t \geq f_3$ , the HL2 signal LED is turned on and a one-shot beep sounds; when $f_t \leq f_3$ (which may indicate the “triggering” of the anti-aerosol filter), the HL3 signal LED is turned on and short beeps sound; if there is no air flow in the line ( $f_t = 0$ ), the LED HL4 and a continuous beep signal that. The status of the battery is indicated using the HL5 signal LED, which flashes when the remaining battery capacity is at least 25-30%; when the voltage on the battery stack drops to 2.8-3 V, the fan turns off, and the HL5 LED lights up continuously.
Increasing air flow	When the S3 button is pressed from the MU, an increased supply voltage is applied to the fan, which is signalled by the HL6 LED.
Switching off	When the S2 button is pressed, the blower is turned off.
Anti-aerosol filter activation alarm	When the anti-aerosol filter is activated during operation, its aerodynamic resistance increases, as a result of which the air flow in the line decreases; if it is impossible to compensate for it due to the intensification of the fan, the “Warning” signal is first activated (the HL3 signal LED flashes and beeps are emitted), and then, with the filter layer resistance increasing, the “Emergency” signal is activated (the HL3 LED is turned on and a continuous sound is emitted).
Battery discharge alarm	When the remaining capacity of the battery decreases to the level of 25-30%, light (HLX) and sound (HA) intermittent “Warning” signals are activated. The air supply does not stop. When the voltage on the battery stack drops to 2.8-3 V, a continuous sound signal “Accident” is turned on, and after ~10 s the turbo block is turned off!

**Source:** developed by the authors

According to the PAPR operation algorithm, control of its operation modes, namely: stabilisation of the amount of normalised air flow supplied to the under-mask (under-helmet) space, control and warning of the user with

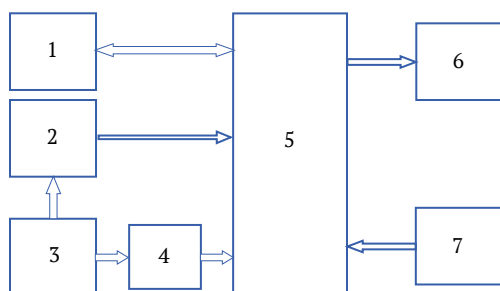
light and sound signals about the “triggering” of the anti-aerosol filter, as well as the autonomous power source (lithium battery), was carried out using an electronic unit whose structural diagram is presented in Figure 2.



**Figure 1.** Schematic diagram of the PAPR for the forced purified air supply into the under-mask space

**Note:** S1-S3 – “On”, “Off” and “Increased air flow” switches, respectively; HL1-HL6 – “On”, “Nominal air flow”, “Replace the filter”, “No air flow”, “Increased air flow” and “Battery discharged” mode indicators, respectively; HA – sound alarm of emergency modes of fan operation

**Source:** developed by the authors



**Figure 2.** Schematic diagram of the electronic control unit for PAPR operating modes

**Note:** 1 – flow driver, 2 – control unit, 3 – battery, 4 – battery discharge controller, 5 – process controller unit, 6 – alarm module, 7 – carbon monoxide level control module

**Source:** developed by the authors

The electronic unit consisted of the following main structural elements:

- a mode control unit, which enabled/disabled PAPR and increased air flow mode;
- a unit for controlling the carbon monoxide content in the air inhaled, which provided conversion and amplification of the signal from a special electrochemical sensor (CO module);
- air flow driver, which consisted of a fan and a tachometer. The fan created the required air flow and was controlled by a pulse width modulation (PWM) signal, and the tachometer converted the fan turbine rotation frequency, which is proportional to the volume flow rate, into electrical pulses suitable for further measurement of the flow rate;

- the process controller unit processed the signals coming from the control unit, CO module and tachometer and, in accordance with the established algorithm, performed PWM signalling to control the frequency of rotation of the fan, as well as light and sound indication of various operating modes of the turbo unit;

- the alarm unit generated warning light and sound signals according to the controller’s commands;

- the battery provided power supply to the components of the turbo unit;

- the battery discharge controller was a combination of a voltage indicator with element-by-element control and a controlled electronic key, which made it possible to organise the disconnection of the battery from the load when any of its elements reaches the critical value of 3.2 V. Implementation of the specified requirements when developing the electronic circuit of the PAPR operating mode control unit is currently possible only with the use of an element base on microcontrollers, i.e. microprocessors with built-in memory devices and other additional functions.

Considering the fact that formation of a gradually growing layer of dust on the filter surface is a peculiarity of the functioning of any individual respiratory protection device, even during the PAPR operation, the increase in the pressure drop across the filter due to the dust accumulation results in an increasing air flow, which necessitated the development/improvement of a simulation model which would take into account this additional resistance to the air flow. At the same time, the amount of dust deposited on the filter was calculated according to the formula (Baek et al., 2024):

$$\Pi_\phi = \frac{2CQt}{F_0}, \quad (1)$$

where  $C$  is the total dust concentration,  $\text{mg}/\text{m}^3$ ;  $Q$  is air flow rate through the filter,  $\text{m}^3/\text{s}$ ;  $t$  is a time interval of respirator operation,  $\text{s}$ ;  $F_0$  is the total area of the filter,  $\text{m}^2$ .

The total resistance of the filter was determined based on the equation (Tcharkhtchi *et al.*, 2021):

$$\Delta p_{total} = \Delta p_0 + \frac{k_n \rho_d \phi F_0^2}{3\pi^2 L} \left[ (F_B^2 + \frac{2\Pi_\phi F_B}{a \rho_n \phi F_0})^{3/2} - F_B^3 \right], \quad (2)$$

where  $\Delta p_0$  is the initial resistance of the clean filter,  $\text{Pa}$ ;  $k_p$  is the proportionality factor which depends on the filtration rate,  $\text{m}^4/\text{s}^2$ ;  $\rho_d$  is the bulk density of dust particles,  $\text{kg}/\text{m}^3$ ;  $\phi$  is the coefficient of uneven distribution of dust on material fibres;  $F_B$  is the total surface of filter fibres;  $L$  is the total length of fibres in the filter,  $\text{m}^{-1}$  (Tcharkhtchi *et al.*, 2021):

$$L = \frac{\beta \cdot H}{\pi \cdot a^2}, \quad (3)$$

$$F_F = \frac{2\beta H}{a}, \quad (4)$$

where  $\beta$  is fibre packing density;  $H$  is the filter layer thickness,  $\text{m}$ ;  $a$  is the mean radius of the fibres in the filter,  $\text{m}$ .

The required battery capacity was calculated according to the formula (Bašić *et al.*, 2023):

$$C = \frac{P \cdot t}{U}, \quad (5)$$

where  $C$  is the battery capacity,  $\text{Ah}$ ;  $P$  is power consumption,  $\text{W}$ ;  $t$  is time,  $\text{h}$ ;  $U$  is battery voltage,  $\text{V}$ .

Considering the importance of the effect of additional resistance from dust accumulation on the powered air-pu-

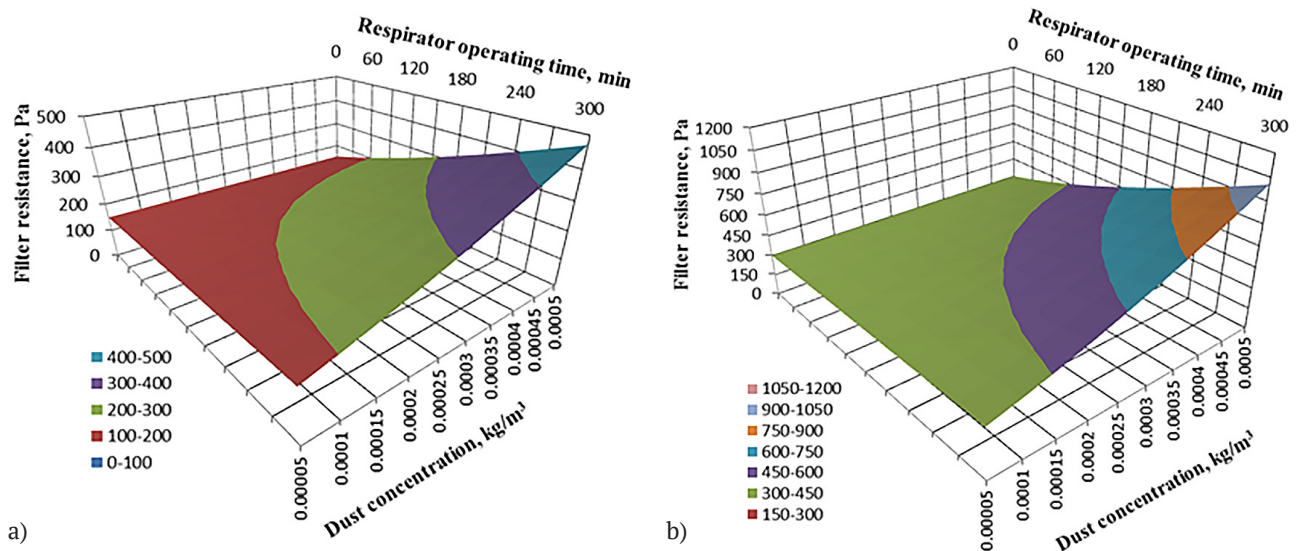
rifying respirator operation, it became necessary to calculate the final filter resistance depending on the period of PAPR application, which, in turn, resulted in a rapid depletion of the power source charge.

For example, it was assumed that a work shift at coal enterprises in underground workings lasts six hours, of which the worker was in the dusty zone for about five hours (an hour was arranged for preparing and completing work) (Wu *et al.*, 2020). That is, the active use of the respirator was to be at least 5 hours. At the same time, the concentration of dust in the air varied from 50 to 500  $\text{mg}/\text{m}^3$ ; the volume flow of air varied from 115 to 260  $\text{dm}^3/\text{min}$ .

Taking into account the fact that the area of the filter membrane of one filter element was 0.005  $\text{m}^2$  (the diameter of the FRPA P2 filter cartridge is 100 mm), the total area of filtration for a respirator with two similar elements was 0.01  $\text{m}^2$ . The filtering element, formed into concentric curved folds (corrugations), was made of non-woven material "Eleflen" (Scientific and Production Enterprise "Standard", Ukraine), with a height of the filtering layer of 4-5 mm, a packing density of 1.1, a fibre diameter of 2-3  $\mu\text{m}$  (Bazaluk *et al.*, 2021). The PAPR provided continuous air purification during 1 working shift (up to 5 hours). The final total pressure drop across the filter should not exceed 800 Pa.

## RESULTS AND DISCUSSION

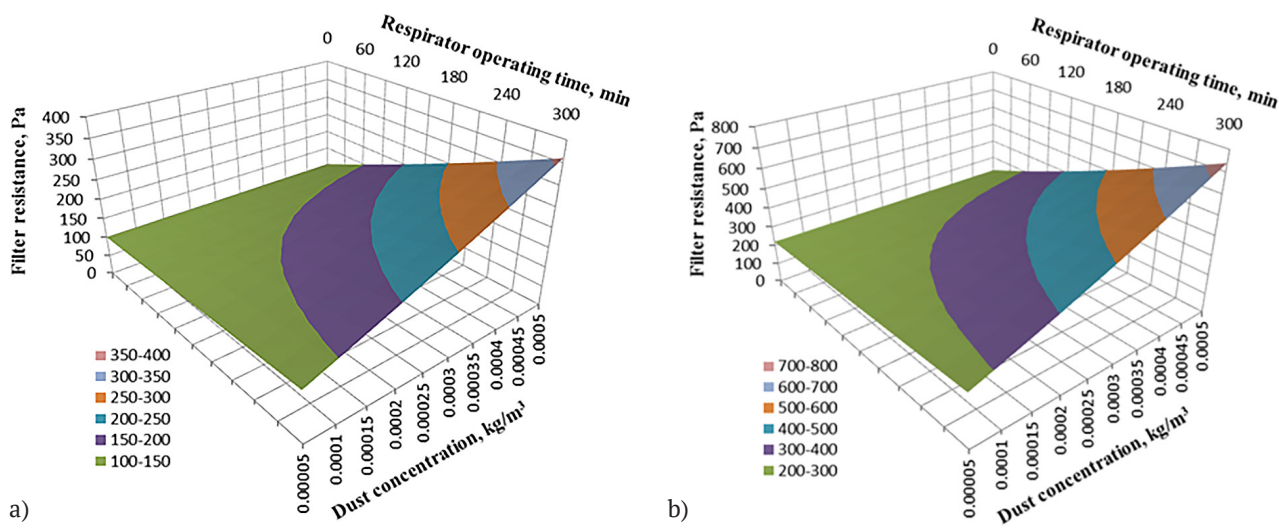
The results of calculating the change in filter resistance from the time of PAPR operation according to the method given in the works by M.A. Boraey (2021) and T. Dziubak (2024) with different dust concentrations are presented in Figure 3 – when using 1 filter and Figure 4 – when using 2 filters.



**Figure 3.** Dependence of the resistance of 1 filter on the operation time and dust concentration

**Note:** a) air flow rate 140 l/min, b) air flow rate 260 l/min

**Source:** developed by the authors



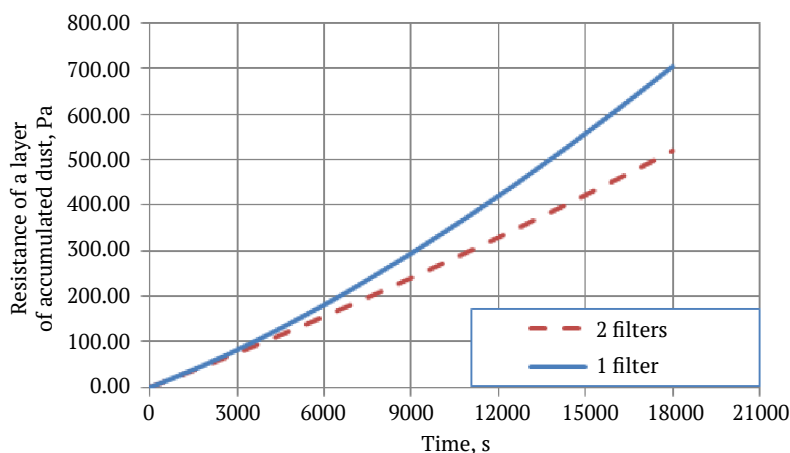
**Figure 4.** Dependence of the resistance of 2 filters on the operation time and dust concentration

**Note:** a) air flow rate 140 l/min, b) air flow rate 260 l/min

**Source:** developed by the authors

This made it possible to plot the dependence of the change in the additional resistance of the filter on the accumulation of dust sediment at maximum air flow and dust concentration relative to the time of operation when using one (Fig. 5, curve 1) and two filters (Fig. 5, curve 2). From this, it was established that in the most unfavourable operating conditions, namely, the

maximum dust concentration and the maximum air flow required the total resistance to air movement at the end of the work shift is 1006 Pa when using one filter, exceeding the norm; when two filters are working, it is equal to 736 Pa. If it is necessary to increase the service life of the PAPR, it is essential to use filters with a larger filtering surface.

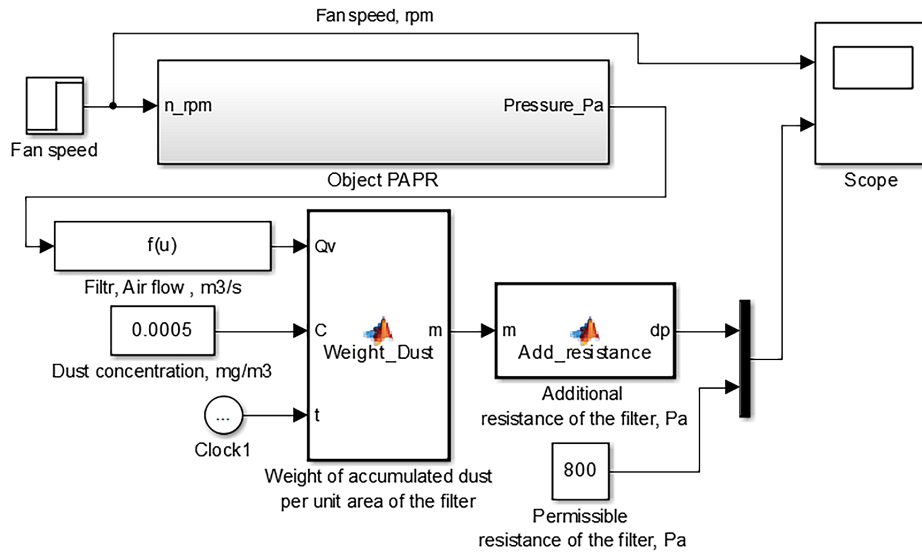


**Figure 5.** Change in the added resistance of the respirator filter from the time of operation at a flow rate of 260 l/min and a dust concentration of 500 mg/m<sup>3</sup> when using one (1) and two filters (2)

**Source:** developed by the authors

Taking into account the schematic scheme of the electronic control unit, which demonstrates the relationships between various components of the PAPR design, as well as the need to take into account the additional increase in resistance on the filter surface due to dust deposits according to equations (1) and (2), the simulation model, which is presented in Figure 6, was

improved (Slavynskiy, 2023). The main parameters of the simulation model included the controlling action – fan rotating speed, restrictions on the maximum additional resistance of the respirator filter, concentration of dust in the air of the working area, parameters of filter elements (fibre packing density, filter layer thickness, fibre diameter and others).

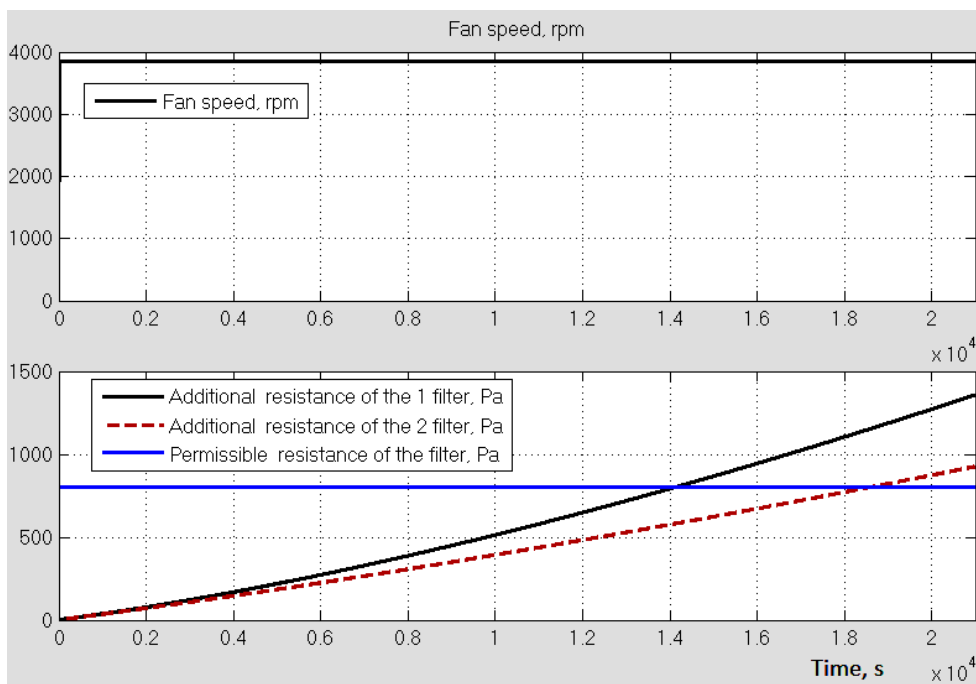


**Figure 6.** A simulation model with the possibility of calculating the additional resistance of the filter against the dust accumulation

**Source:** developed by the authors

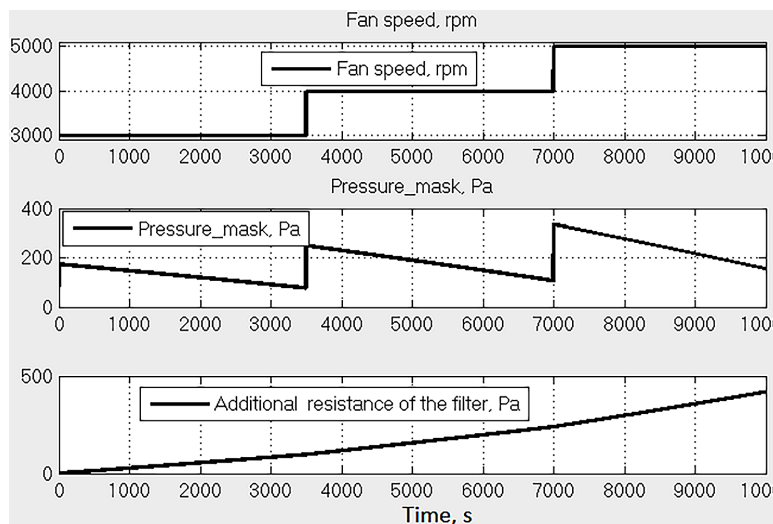
The results (Fig. 7) of the simulated modelling of the change in the additional resistance of the filter due to the accumulation of the dust layer correspond to the calculated ones (Fig. 5), so the developed functions can be applied in the further research. Verification of the operation of the

simulated model of the powered air-purifying respirator, whose structural diagram is presented in Figure 8, under different modes of air supply is shown in Figure 9 as well as when adding the simulated signal “Breathing” (with the scaling of the dust accumulation rate 1:100).



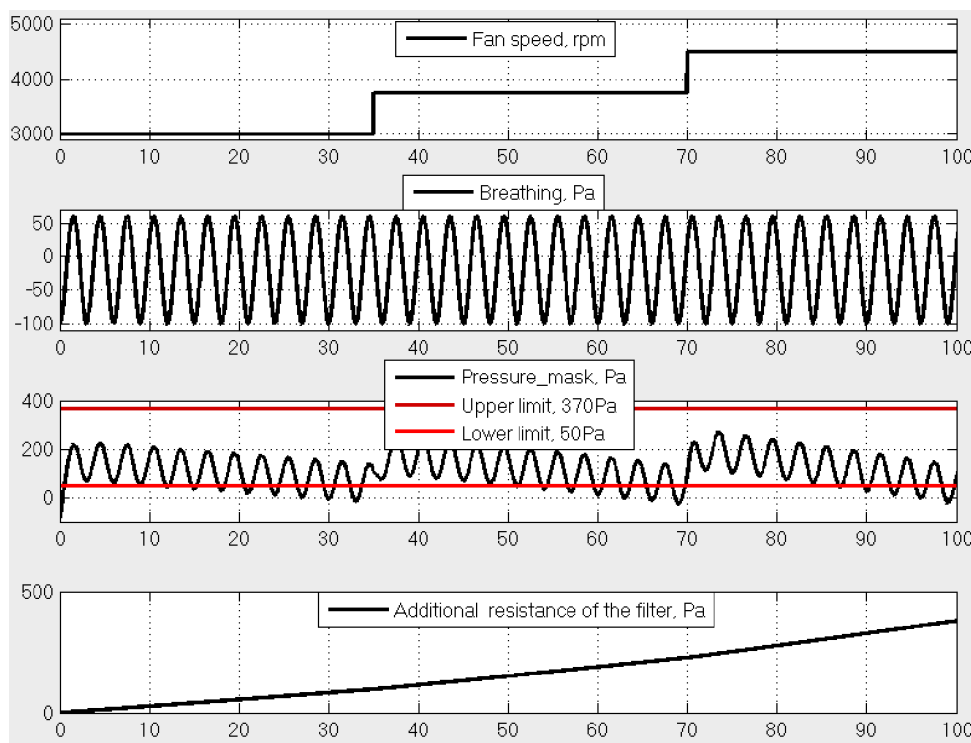
**Figure 7.** The results of modelling the function of changing the additional resistance of the filter from the dust accumulation

**Source:** developed by the authors



**Figure 8.** The result of the simulation model operation when the flow rate changes as a controlling action in different operating modes

Source: developed by the authors



**Figure 9.** The result of the simulation model operation when adding a breathing signal

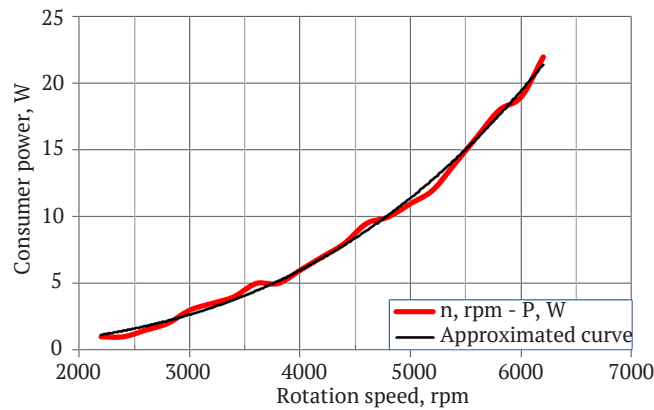
Source: developed by the authors

As can be seen from Figure 9, the drawback of the powered air-purifying respirator operation is a drop in the air pressure in the mask beyond the lower permissible limit (below 50 Pa), caused by a change in the pressure drop across the filters due to the lack of a sufficient and timely

compensation signal to increase the air supply. This requires an appropriate research on the effect of the change in the additional resistance of the filter due to the dust accumulation on the process of supplying air to the mask, which will ensure the necessary mode of PAPR operation.

When operating the PAPR, an important characteristic is the time of continuous operation from an autonomous power source – the battery. To determine the time of continuous PAPR operation from an autonomous power source,

a research was previously conducted to determine the dependence of the consumed electric power of the electronic and electromechanical elements of the control system of the powered air-purifying respirator on the fan speed (Fig. 10).



**Figure 10.** Dependence of power consumption on fan speed

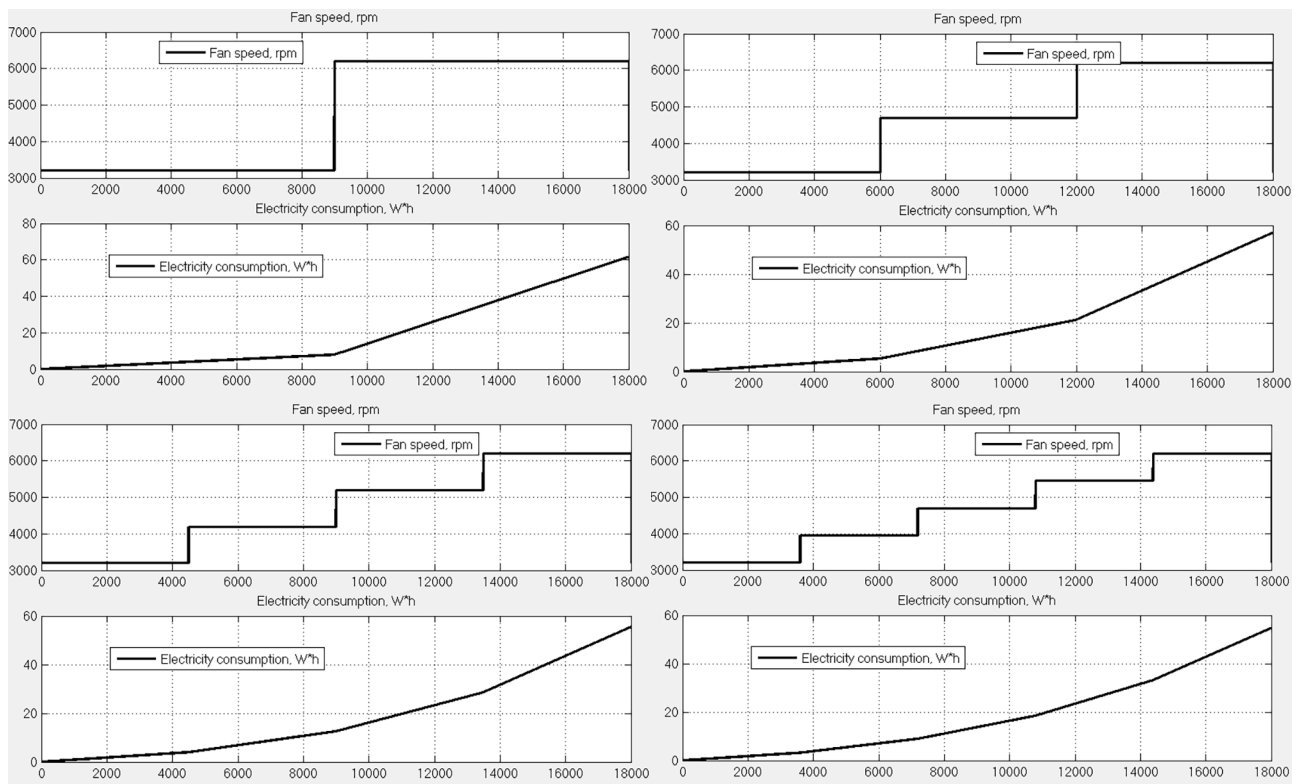
**Source:** developed by the authors

The equation of the approximate dependence of the consumed power on the fan speed is:

$$y = 8.72E - 11x^3 + 1.50E - 09x^2 + 9.65E - 05x. \quad (6)$$

Equation (6) being used for the simulation model presented in Figure 9, the possibility of calculating electricity consumption during the operation of a powered

air-purifying respirator in the mode of step change of the control signal – fan speed (2-5 levels) was added. The following assumptions were made to conduct the experiment: the levels of the speed change are switched evenly on the time scale and in magnitude, the reverse switching of the levels is not allowed. The simulation results are presented in Figure 11.

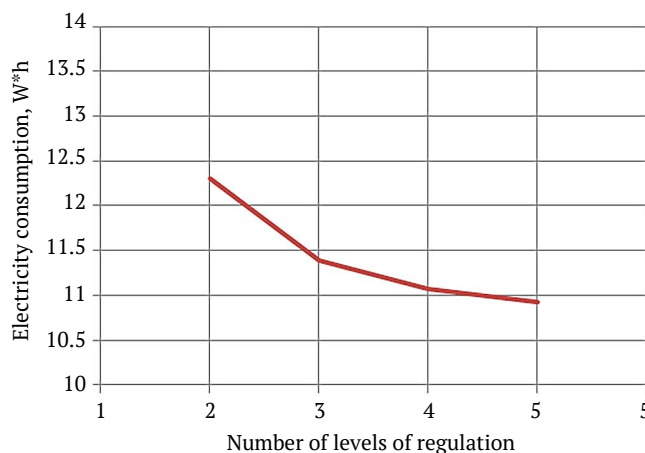


**Figure 11.** Simulation modelling of electricity consumption during of a powered air-purifying respirator operation in the mode of a step change in the fan speed

**Source:** developed by the authors

The results of simulation of electricity consumption on a simulated model of a powered air-purifying respirator

made it possible to obtain the dependence of electricity consumption on the number of adjustment levels, Figure 12.



**Figure 12.** Dependence of average electricity consumption on the number of adjustment levels

**Source:** developed by the authors

Thus, when increasing the fan speed adjustment levels, for series compensation of the increase in additional resistance on the filter surface, the power consumption is reduced, which allows the use of a battery with a smaller capacity. To ensure continuous operation of the powered air-purifying respirator in autonomous mode at 2 levels of fan speed for 5 hours, the required battery capacity with a voltage of 7.4 V will be:

$$C = \frac{61.54}{7.4} = 8.32 \text{ Ah or } 8320 \text{ mAh.}$$

In view of the standard nomenclature range of storage batteries and taking into account the required reserve capacity at the level of 20%, a battery with a voltage of 7.4 V and a capacity of 10000 mAh can be accepted for use. The obtained curves for the power source as a whole were used when setting the PAPR alarm when the permissible limit level of battery discharge is reached.

As a result of the work performed, the relationship between the change in the breathing resistance of the filters and the discharge of the power source was established, which allows estimating the period of safe operation of the powered air-purifying respirator, based on the concentration of dust in the air of the working area and the user's working arrangements.

Similar results were obtained in the work by S. Wood (2020); however, when developing a simulation model, the author described the operation of the respirator through an analytical method, using the appropriate equations and formulas for individual components. At the same time, the resulting model had several important assumptions and simplifications: the change in filter resistance due to dust accumulation during respirator operation was not considered.

The research by B. Shi *et al.* (2019) analysed the geometric characteristics of the filter, which can increase the

efficiency of dust particle capture. The effect of variable air flow on the filter's ability to retain dust over a long period of use is also considered. The emphasis is placed on the relationship between the area of the filter surface and its ability to accumulate dust without reducing efficiency. In addition, the work simulates the behaviour of the filter under the influence of different levels of contamination in order to optimize its operation in real operating conditions.

The work by N. Wagner (2012) was aimed at developing a mathematical model for regulating air supply to the undermask space of a respirator based on the control of a centrifugal fan in automatic mode. The authors reached a number of important conclusions, which were later used when developing a simulation model. In particular, the authors established a relationship between the fan speed and the air flow to the mask, but did not take into account the change in the transmission coefficient in the system when the rotation speed changes in the case when the user needs more air. However, only the case of increased air flow fluctuations in the system was considered when simulating an increase in the depth (amplitude) of the user's breathing, and it was noted that the control system creates prerequisites for delaying the air flow due to a sharp change in the breathing mode when the physical load increases.

The current studies have shown that when using the PAPR, there is a gradual increase in the resistance of the filter elements due to the accumulation of a dust layer, which affects the speed of rotation of the fan blades. As a result, there was a need to develop a simulated model of a powered air-purifying respirator, based on which there are empirical dependencies between the change in filter resistance, the amount of air, and the concentration of dust in the working area air. This made it possible to estimate the additional resistance of the filter due to the accumulation of a dust sediment layer. At the same time, it was assumed that the dust aerosol mostly accumulated on the surface of

the filter and did not penetrate deep, creating an additional auto-filtering layer of dust.

## CONCLUSIONS

A simulated model of the powered air-purifying respirator has been developed based on its physical model, with allowance for the empirical dependence of the change in the resistance of the filter elements during the accumulation of dust sediment, which takes into account the flow of the air through the filter and concentration of dust aerosol in the air of the working area. The following parameters of the simulated model of the powered air-purifying respirator are substantiated: controlling action – fan rotating speed, restrictions on air flow and air pressure in the respirator mask (it depends on the working arrangements of the user), concentration of dust in the working area air, capacity of the power source, power consumption of the electric motor of the fan and components of the control system, filter element parameters (fibre packing density, filter layer thickness, fibre diameter, etc.), input dust aerosol concentration, which made it possible to establish the relationship between the filter element resistance and the time to complete discharge of the power source.

Simulation modelling of electricity consumption during the operation of a powered air-purifying respirator in the mode of a stepped variation in the fan rotating speed made it possible to establish the dependence of the average electricity consumption on the number of adjustment levels, taking into account two filter elements, and to obtain the equation of the approximate dependence of the consumed power on the fan rotation speed.

A critical value of the resistance of the powered air-purifying respirator filter elements was established, which leads to a significant discharge of the power source, based

on the different flow rate of air supplied to the undermask space at a given concentration of dust in the working area. The dependence was determined of the electrical power consumed by the powered air-purifying respirator on the fan rotating speed, which was introduced to the simulation model. According to the simulation results, it was established that with increasing levels of fan rotating speed, the average electrical power consumed decreases, which affects the required battery capacity.

To ensure the continuous operation of a powered air-purifying respirator in autonomous mode with two filters with a total filtering area of 0.01 m<sup>2</sup> and a resistance of 500 Pa at an air flow rate of 140 dm<sup>3</sup>/min, with a dust concentration of 0.002 kg/m<sup>3</sup> at 2 levels of fan rotating speed for 5 hours, battery capacity with a voltage of 7.4 V 8320 mAh is required.

Further on, with the implementation of the air pressure control system in the mask of the powered air-purifying respirator, the average power consumption may decrease, consequently, reducing the battery capacity requirements. Considering the fact that the battery capacity determines its weight and cost, this will also reduce the finished cost of the device. The introduction of a powered air-purifying respirator, as the main means of individual respiratory protection at mining enterprises, should, in the long term, improve the health of workers who perform their professional duties in conditions of excessive dust concentration in the working area air.

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## CONFLICT OF INTEREST

None.

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**Дослідження впливу опору фільтруючих елементів  
на термін експлуатації моторованих респіраторів**

**Анотація.** Метою дослідження було визначення впливу зростання опору фільтруючих елементів на термін експлуатації моторованих фільтрувальних респіраторів під час експлуатації в гірничих умовах та обґрунтування параметрів джерела живлення респіратора. Дослідження проводилося методом комп'ютерного імітаційного моделювання роботи моторованого респіратора, що дозволяє обчислити додатковий опір фільтра через накопичення пилу. Імітаційна модель моторованого респіратора була створена на основі його фізичної моделі та, з урахуванням емпіричної залежності зміни опору фільтрувальних елементів при осіданні пилу, дозволяє визначити витрату повітря через фільтр та концентрацію пилового аерозолу в повітрі робочої зони. Обґрунтовані параметри імітаційної моделі моторованого респіратора: керуючий вплив – швидкість обертання вентилятора, обмеження по витраті повітря та тиску повітря в масці респіратора (залежить від режиму фізичної роботи користувача), концентрація пилу в повітрі робочої зони, ємність джерела живлення, споживану потужність електродвигуна вентилятора та компонентів системи керування, параметри фільтрувальних елементів (щільність пакування волокон, товщину фільтруючого шару, діаметр волокон та інше), вхідну концентрацію пилового аерозолу, що дозволило встановити залежність між величиною опору фільтрувальних елементів та часом до повної розрядки джерела живлення. Встановлено критичну величину опору фільтрувальних елементів моторованого респіратора, яка призводить до значного розряду джерела живлення, виходячи з різної витрати повітря, що подається у підмасковий простір при заданій концентрації пилу в робочій зоні. Встановлено залежності між зміною опору дихання фільтрів і розрядом джерела живлення, що дозволяє встановити термін безпечної експлуатації моторованого респіратора, виходячи із концентрації пилу в повітрі робочої зони та режиму роботи користувача. Практичне значення полягає у визначенні терміну експлуатації моторованого респіратора, виходячи з критичної величини опору фільтра, який призводить до швидкого розрядження джерела живлення.

**Ключові слова:** керуючий вплив; імітаційна модель; об'єкт керування; ідентифікація; дослідження; витрата повітря; акумулятор; електроенергія; тривалість роботи