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Improvement of the design of the motorized filter respirator

Abstract. Working conditions often do not meet the regulatory requirements for hygienic indicators, specifically, there are violations regarding the presence of harmful impurities in the air of the working area. In such cases, motorized filter respirators are used to protect respiratory organs, which require the development of a suitable system for managing operational indicators for effective operation. The purpose of this study was to improve the control system of a motorized filter respirator to increase protective efficiency. To create a suitable control system, a structural-parametric synthesis of performance indicators' management was applied, based on the relationships between the main variables (outgoing regulated variables, controlling influences and disturbances). A new working scheme of the control object with selected design elements of the blower was developed, the main difference of which is the use of the Arduino Uno R3 board, the LCD Keypad Shield module with a two-line display for controlling the airflow modes, according to the change in the resistance of the filter considering the accumulation of dust sediment assuming that the transfer function can be represented by an aperiodic link of the 1st order with sufficient accuracy for practice. To work out the operating modes and determine the duration of the protective effect, a software model of the operation of the motorized filter respirator was created, which

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helped evaluate the influence of the dust concentration on the change in airflow through the filter elements, considering the accumulation of dust sediment on the protective effectiveness. Recommendations were developed to ensure the effective functioning of the protective device pursuant to the requirements under the most adverse conditions. The practical significance of this study is that thanks to the improvement of the control system of the motorized filter respirator, more comfortable and effective protection is provided, specifically in conditions of severe or hazardous working environments

Keywords: fan; pressure; rotation speed; dust concentration; air flow; pulse width

INTRODUCTION

Working conditions, according to the hygienic indicator (harmful impurities in the air of the working zone), quite often do not meet the regulatory requirements (Kramchaninova *et al.*, 2020). Even with the application of collective means of protection of workers, it is frequently not possible to ensure the maximum permissible levels of hazardous substances in the air of working zones (Aggarwal *et al.*, 2020). M.J. Antonini *et al.* (2021) noted that in such cases, filtering means of individual respiratory protection (hereinafter – IRP) are typically used. However, they are characterized by rather low protective properties. A.N. Bui *et al.* (2021) investigated that this is due, foremost, to the mismatch of the IRP to the anthropometric parameters of the user's face, the presence of hair or scars, which leads to the emergence of a significant suction of unfiltered air due to the lack of tightness between the IRP mask and the face. Motorized filter respirators were developed to solve this issue. A.K. Cramer *et al.* (2021) proved that the main difference between them and ordinary filtering IRP is the creation of excess pressure in the space under the mask, which makes it impossible for harmful impurities to enter the user's respiratory organs, due to leakage, behind the obturation strip (the strip of adhesion of the half mask to the face). However, the emergence of such motorized IRP led to the emergence of new urgent problems, which are related to the correspondence of air supply to the under-mask space to the physiology of breathing, which depends on the pace, rhythm, and difficulty of work (Golinko *et al.*, 2020). Furthermore, it is necessary to provide convenient design parameters (weight of the filtering respirator, breathing resistance, fogging of the mask), which would not lead to other inconveniences during their operation. To solve these problems, a control system is used for the operational parameters of motorized filter respirators: the amount of air supply, the resistance of the filters, the charge of the power battery. However, the main issue of such control systems is the speed of ensuring the necessary operating mode, the lack of control over the duration of the protective effect of the filters, which will ultimately affect the protective efficiency. The conclusion made is reflected in the latest scientific research.

M.Y. Kim *et al.* (2021) presented the results of a study on the influence of the amount of airflow on the level of air purification in the filter elements of motorized filter respirators. Specifically, the authors considered the possibility of cleaning filters from settled dust by applying a reverse flow of air. The study determined the time to ensure an acceptable level of airflow resistance. However, as the authors themselves note, this procedure requires a fairly considerable period of time, which does not allow for the appropriate exploitation of such IRP. In addition, for such motorized filter respirators, combined filters are mostly used to protect against dust and harmful gases. Unfortunately, purging the filters is ineffective for restoring the gas component of the latter. In another study, V. Jayan *et al.* (2020) set out to develop an innovative design of a motorized filtering respirator with a low cost. To reduce the cost of the design, it was suggested to use a flexible plastic headband, a hood made of polypropylene non-woven fabric, as well as to abandon the control systems for the movement mode of the airflow, which in the final version does not allow this respirator to be used for work that is characterized by a different pace and rhythm of work because the amount of air supplied by the fan under the hood is constant.

T.S. Alderman *et al.* (2016) addressed the issue of the reduction of protective effectiveness in case of incorrect installation of filters, e.g., when replacing during work, in an uncomfortable position. As a result, the conditions were determined when the IRP does not provide adequate protective effectiveness. The lack of evaluation of the effectiveness of control systems for the operation of such respirators should be attributed to the shortcomings of this study. Thus, the existing pressure drop sensors must necessarily report, through corresponding signals, about depressurization of the system, in case of incorrect placement of the filter in the blower or the use of a filter of the wrong design. A. Licina *et al.* (2020) made a powerful analysis of over 50 studies on the effectiveness of the designs of motorized filter respirators, which strongly suggested that the main disadvantages of such respirators are overheating, reduced mobility, limitation of the field of vision, fogging, which are related to the inefficiency of the control system in motorized filter respirators. For instance, regarding overheating or fogging of the glass, M.Z. Chaari *et al.* (2020) claimed that it is possible to predict the mode of cooling or dehumidification of the air. Based on the analysis of the latest publications, it can be concluded that the task of ensuring the control of motorized filter respirators, which will ensure the suitable protective efficiency during the given period of operation, is still relevant. Furthermore, the presence of an uncomfortable feeling can also be prevented by the possibility of controlling the mode of air movement, which requires the suitable development of software models.

The purpose of this study was to improve the control system of the motorized filter respirator to increase the protective efficiency, by developing an innovative parametric scheme of the control object considering the functional relationships between the operating mode, airflow, filter resistance, and the term of protective action.

To fulfil the purpose, it was necessary to perform the following tasks: develop a structural diagram of the control object and select all the structural elements of the blower of the motorized filter respirator; conduct a parametric synthesis of the information and control system of the motorized filter respirator to improve the management system of operational indicators; determine the modes of movement of the airflow in the blower of the motorized filter respirator according to the change in the resistance of the filter, considering the accumulation of dust deposits to determine the term of protective action and protective efficiency.

MATERIALS AND METHODS

To perform the scientific research, a structural-parametric synthesis of a motorized filter respirator was used, which allowed to choose a variant of the working scheme. For this, a certain rank of the control system was synthesized at each level of development of its design. Firstly, a general control scheme for the work of the filtering IRP was formed, then a functional scheme of the interaction of structural elements, which helped pick the suitable components of the motorized filtering respirator. For the latter, a heuristic method was used, which relied mainly on the erudition and intuition of the designer. Therewith, the experience and knowledge of previous developments and analogues underlay the development of the design of the motorized filter respirator (Cheberyachko *et al.*, 2022). Thanks to the parametric synthesis of the motorized filtering respirator, the task of improving the management system of operational indicators was solved based on establishing the main interrelationships of its constituent elements of the filtering IRP design. Therewith, to ensure the performance of the automatic control system (hereinafter – ACS) of the blower, it was necessary to define a mathematical model that required the definition of the relationships between the main variables (output adjustable variables, controlling influences and disturbances) and the restrictions imposed on them. There are various (static and dynamic) types of mathematical models, but in practice, transfer functions are most widely used to determine which analytical and experimental methods of identification are used. Creating a mathematical model of the blower control system assumes that the transfer functions of all its components are already known. The use of transfer functions of individual constituent elements of the control object to obtain its mathematical model is a rather challenging task and cannot guarantee the correspondence of the obtained result to the real object. For the convenience of the identification procedure, all components of the control object were combined into one transfer function (Fig. 1).

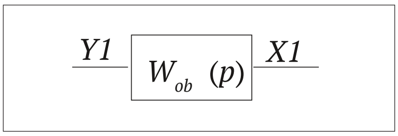

Figure 1. Simplified structural diagram of the blower control object

Note: $W_{ob}(p)$ – the transfer function of the motorized filter respirator control object; $X1$ – air pressure in the mask, Pa; $Y1$ – task signal for the control object – fan rotation speed, rpm

Source: developed by the authors

The transfer function of a W_{ob} object combines the transfer functions of a blower motor, a fan blade, a flexible pipe, a mask, and a filter. With this simplification in mind, the task of identifying a motorized filtering respirator was described as determining the functional relationship between the task signal to the fan speed regulator $Y1$ and the air pressure in the respirator mask $X1$. Considering the design of the motorized filter respirator, which is similar to ventilation systems, it was possible to suggest that the transfer function with sufficient accuracy for practice can be represented by an aperiodic link of the 1st order (Kadhim & Obed, 2018; Jovanović *et al.*, 2022):

$$W(s) = \frac{Y(s)}{X(s)} = \frac{k}{Ts+1}, \tag{1}$$

where k is the amplification factor, which is the ratio of the output value to the input value in the static (steady) mode, Pa/rpm.; T is the time constant characterizing the inertia of the object (duration of the transient process), $T>0$, time, s; s is the independent complex variable, $s=\sigma+-j\omega$. σ is the real part of a complex number, $j\omega$ is the complex frequency domain, ω is the frequency variable Fourier transform, j is the imaginary unit, a number that, when squared, gives a negative unit: $j^2=-1$. The aperiodic link of the 1st order has a mathematical description in the form of a differential equation:

$$T \cdot \frac{dy(t)}{dt} + y(t) = k \cdot x(t), \tag{2}$$

where $y(t)$ is the initial value (coordinate) of the system, pressure, Pa, $x(t)$ is the system input coordinate fan rotation speed, rpm; k is the amplification factor, Pa/rpm; T is the time constant, s.

To obtain the transfer functions for the aperiodic units of the first order of the motorized filter respirator, the Process Models in System Identification Toolbox method was used in the MATLAB Online software. Subsequently, the obtained transfer functions were used to develop a software model in the SolidWorks software environment. The task of identification was performed through an active experiment with the blower of a motorized filter respirator. The method of active experiment (transient characteristics) is based on the use of artificial disturbances affecting the delta momentum of the object according to a plan created in advance (Vladov *et al.*, 2020).

Identification of signals from blower sensors of a motorized filter respirator according to the method of transient characteristics has several advantages: the test step signal is a typical control signal of comparable objects; the prevalence of parametric object identification methods based on this type of signal; the experiment using the method of transient characteristics does not require a change in the physical structure of the experimental sample of the motorized respirator.

To control the value of air pressure in the rarefaction zone and in the mask of the motorized respirator, pressure sensors were used – MPXV7002DP (piezoresistive differential pressure sensor), with a measurement range from -2 kPa to +2 kPa, sensitivity 1.0 V/kPa, analogue output: 0.5 V-4.5 V and a response time of 1 m (manufacturer: NXP Company, Netherlands). To rotate the centrifugal fan, an electric motor model BFB1012VH-AF00 (manufacturer: RTS-Ukraine Company, Ukraine) was used. To reduce air pressure fluctuations in the specified zones (changes in airflow due to fan rotation), a brushless electric motor of the BLDC – Brushless DC Motor model, BL 2208/8 Brushless Outrunner 2200 kv, with a speed of up to 18,000 rpm and a voltage of up to 11.1 V (manufacturer: Hobby Star Company, Taiwan). The speed of rotation of the motor rotor was controlled using an electronic speed controller – model ESC – Electronic Speed Controller – Skywalker 40A. Speed control was based on pulse width modulation (Manufacturer: Hobbywing Technology Co., Ltd, China). The collection of information from the sensors and the change in the speed of rotation of the fan was provided by the controller model Arduino Uno R3 (Manufacturer: Arduino Company, China), which is loaded with the corresponding software, developed by the author of this study.

To monitor the current state of the sensors and select the required motor speed, an LCD Keypad Shield module compatible with the Arduino Uno R3 controller was connected with a two-line display (16 characters in each line) and 6 buttons (only 5 can be engaged of them, the 6 button is responsible for the hardware reset of the controller) (Manufacturer: DF Robot Company, China).

Excel Microsoft 365 program was used to process the experimental data, to construct approximation curves of the dependences of the fan blade rotation speed on the pulse width of pulse width modulation (PWM) and the filter resistance on the fan rotation speed.

RESULTS AND DISCUSSION

To develop a structural diagram of the control object of a motorized filter respirator and to select the design elements of the blower, the main relationships of its constituent elements, which are different in nature – pneumatic (related to air movement: filter, fan blade, flexible pipe, with connected mask, inhalation/exhalation valves) and electrical (speed controller and fan motor) and is quite a complex object. Thusly, it was presented the structure of the researched control object – a motorized filter respirator (Fig. 2).

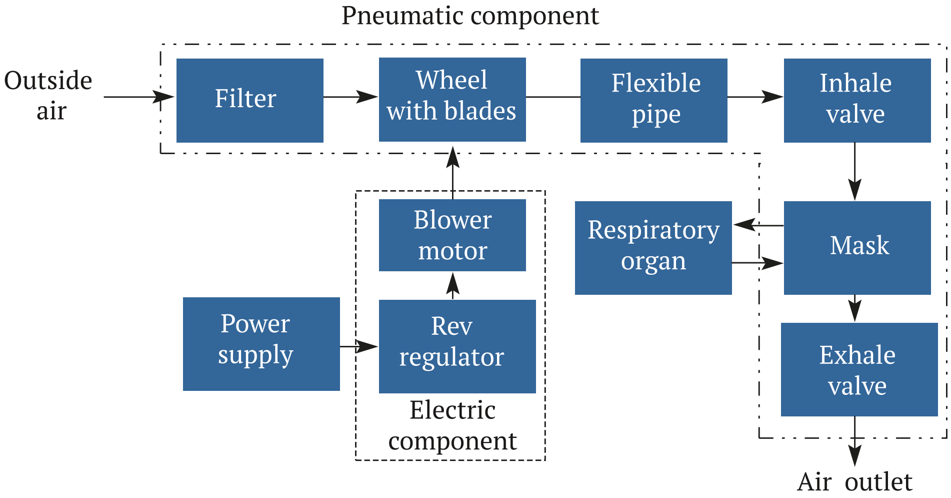

Figure 2. Structural diagram of the control object
Source: developed by the authors

The development of the structural diagram of the motorized filter respirator helped present the design of its blower (Fig. 3), the main difference of which is the use of a centrifugal fan for air supply, which will provide a much better aerodynamic performance in terms of the airflow/pressure ratio, compared to the axial fans used in analogous motorized filter respirators (Johnson & Johnson, 2018; Tran *et al.*, 2021; Nagel *et al.*, 2021). Furthermore, the proposed design provides the possibility, thanks to ACS, to operate with various input parameters (breathing resistance, temperature, air humidity, amount of air supply) to determine the pressure drop in the zone (1, 2) and the fan (3) and excess pressure in full-face mask with an assessment of the effect on the protective properties of the IRP.

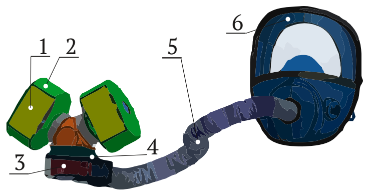

Figure 3. Design of the air supply unit: filter (1), filter box (2); centrifugal fan (3); housing (4); corrugated duct (5); full-face mask (6)
Source: developed by the authors

The connection diagram of the electronic components of the experimental sample of the blower is presented in Figure 4.

For the convenience of performing experiments and checking the operation of the fan motor, data on the change in fan rotation speed from the width of the PWM pulses were obtained. The required value of the pulse width was supplied to the input of the electronic speed controller of the brushless motor, the rotation speed was controlled using a non-contact laser tachometer. The dependence of the fan blade rotation speed on the PWM pulse width is presented in Figure 5.

The initial value of the test signal is the value of the PWM pulse width, which is supplied to the electronic speed controller, can be left zero (for the electronic speed controller of the brushless motor, this signal ranges from 800 μs to 2,300 μs at a frequency of 50 Hz) (Kothakonda *et al.*, 2021).

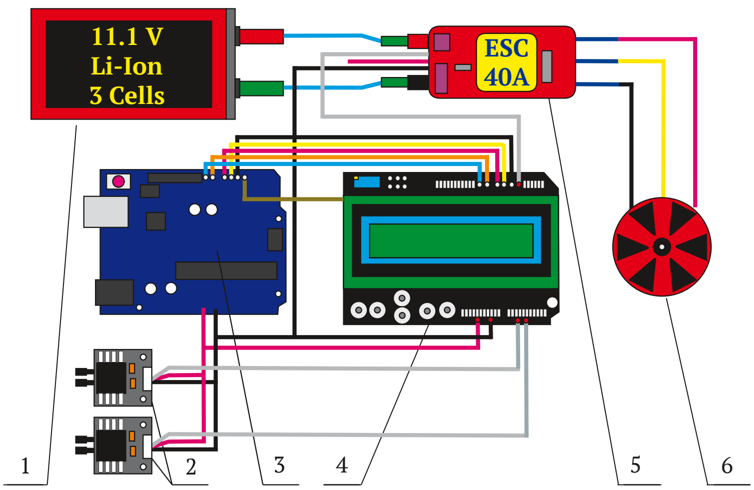

Figure 4. Connection diagram of the electronic components of the blower
Note: 1 – rechargeable battery Li-Ion 11.1 V; 2 – differential pressure sensors MPXV7002DP; 3 – board based on microcontroller ATmega328p – Arduino Uno R3; 4 – LCD Keypad Shield module; 5 – electronic speed controller ESC Skywalker 40A; 6 – brushless electric motor BL 2208/8
Source: developed by the authors

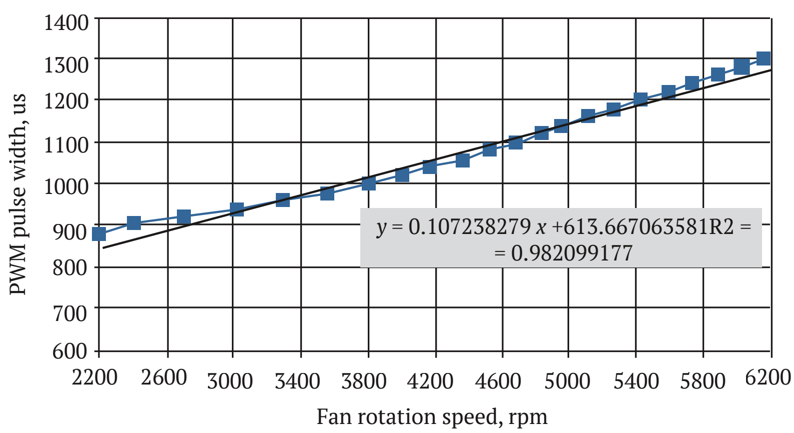

Figure 5. Dependence of fan blade rotation speed on PWM pulse width
Source: developed by the authors

The final value of the test signal is selected considering the permissible value of the air pressure in the mask (up to 370 Pa, accordingly). If the air pressure exceeds the permissible value, it is necessary to repeat the experiment, reducing the value of the control influence on the executive device.

For further experiments, using the obtained dependence (Fig. 5), using linear approximation in Microsoft Excel 365, an equation of the following form was obtained:

$$y = 0.107238279 \times x - 613.667063581, \quad (3)$$

where x is the fan blade rotation speed, rpm; y is the PWM pulse width, µs.

The coefficient of determination of the obtained equation was $R^2 = 0.9821$, i.e., the equation over 98% corresponds to the experimental dependence of the rotation speed of the fan blade on the PWM pulse width. When performing an experiment, the main task is to determine the parameters of the test signal – the control effect on the executive device. For the test step effect, the parameters are as follows: the initial value of the signal, the final value of the signal, and the time of the signal (switch-on moment). Considering the specific features of the operation of the electronic speed regulator, the range of adjustment of the speed of rotation of the fan motor was chosen within 0-6,200 rpm (Fig. 6).

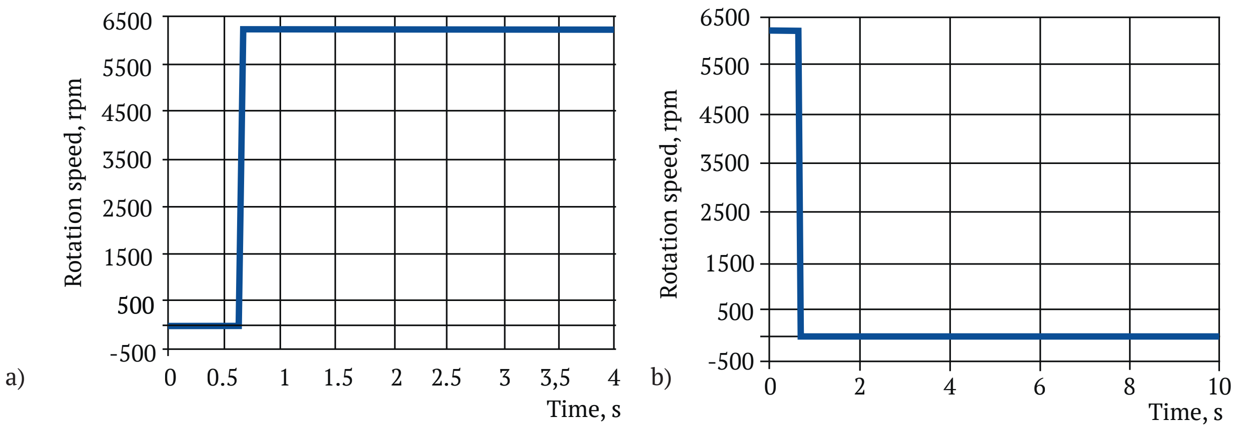

Figure 6. Step test signal

Note: a) – from 0 to 6,200 rpm, b) – from 6,200 to 0 rpm

Source: developed by the authors

The transient characteristics presented in Figures 7a, 7b were used to obtain the transfer functions of the motorized filter respirator using the Process Models in System Identification Toolbox method in the MATLAB Online software for first-order aperiodic units:

- transfer function when sending a signal to increase the control influence (Fig. 7a, increasing fan speed):

$$0.59287 \cdot \frac{dy(t)}{dt} + y(t) = 0.22866 \cdot x(t) \quad 4)$$

- transfer function when sending a signal to reduce the control influence (Fig. 7b, reduction of fan speed):

$$0.6542 \cdot \frac{dy(t)}{dt} + y(t) = 0.21038 \cdot x(t). \quad (5)$$

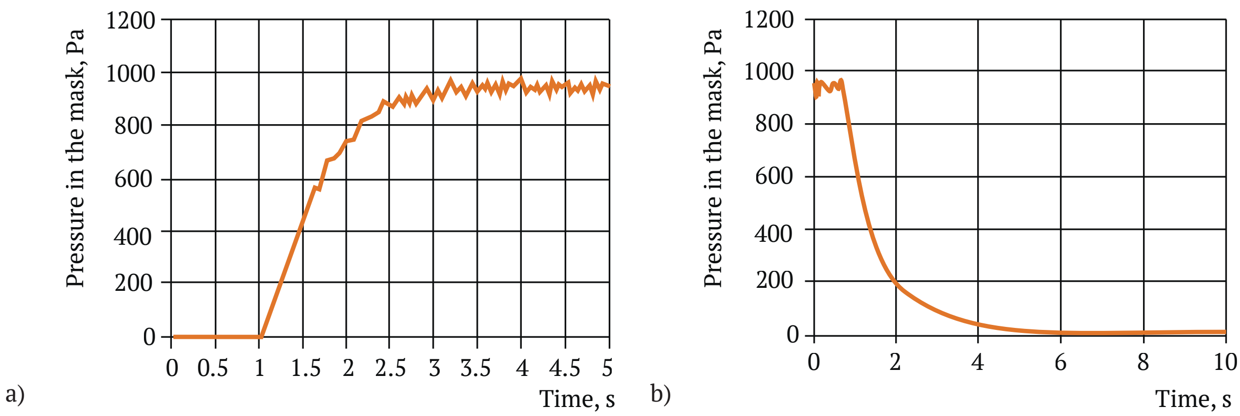

Figure 7. Averaged transient characteristics when applying a test signal

Note: a) – on increasing the controlling influence, b) – on decreasing the controlling influence

Source: developed by the authors

The difference between the time constants when the controlling influence increases and decreases is explained by the technical features of the electronic speed controller (Tanchak *et al.*, 2022). Using the obtained transfer functions, a software model was developed in the SolidWorks software environment, which helped conduct a series of experiments to investigate the influence of dust concentration and changes in airflow through the filter elements on the resistance of the filter, considering the accumulation of dust sediment (Fig. 8).

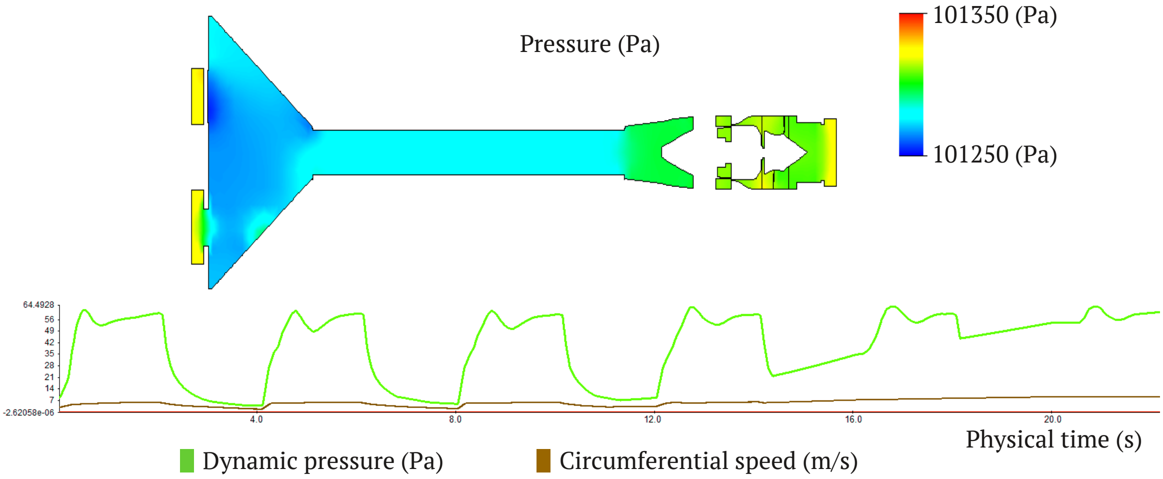

Figure 8. Software (software model) for investigating the operation of a motorized filter respirator
Source: developed by the authors

As a result of the processing and calibration of the received signals, the dependence of the filter resistance on the speed of rotation of the fan was determined (Fig. 9, Fig. 10), which allows controlling the required amount of air in the sub-mask space of the full-face mask of the motorized filter respirator. To determine the effect of dust concentration and airflow on the increase in filter resistance during a certain time (5 hours), an empirical relationship was used (Worker Health & Safety 2020). The obtained results indicate that in the most unfavourable operating conditions: the maximum concentration of dust and the maximum necessary airflow, when using one filter, the total resistance to air movement at the end of the work shift is 1,016 Pa, exceeding the norm, and when two filters are working, it is equal to 756 Pa, which fully satisfies the requirements (Bence *et al.*, 2022). If it is necessary to increase the service life of the filter respirator, it is necessary to use filters with a larger filtering surface.

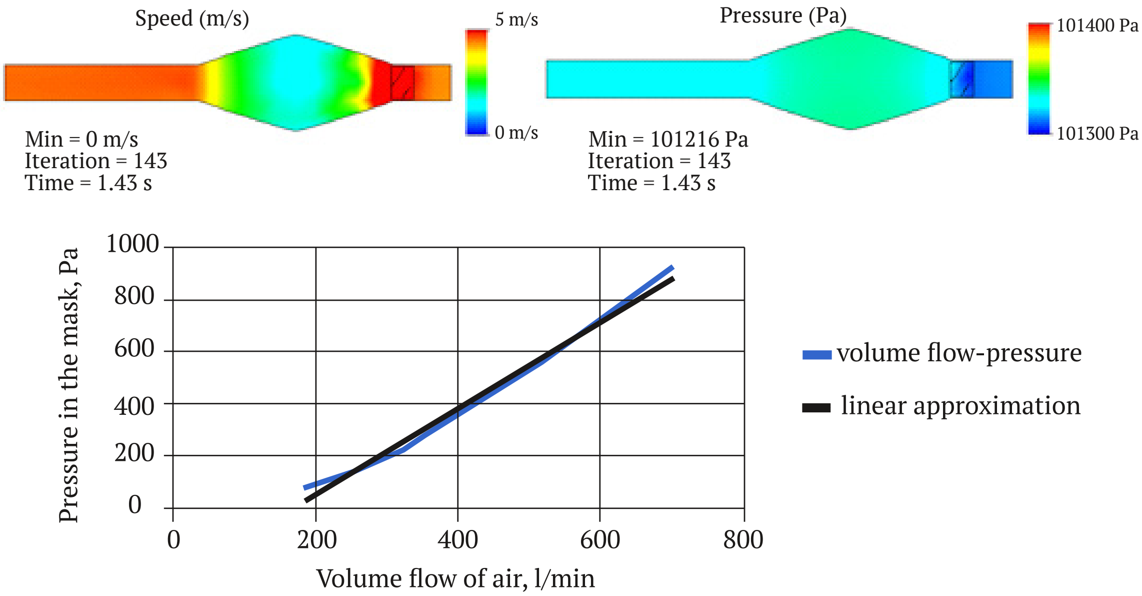

Figure 9. Dependence of filter resistance on fan rotation speed
Source: developed by the authors

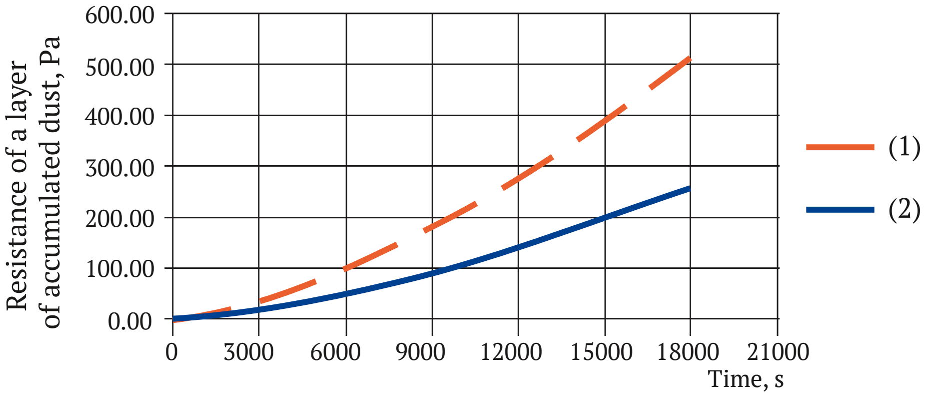

Figure 10. Change of the added resistance of the motorized filter respirator
Note: (1) – with flow rate: 260 l/min and dust concentration of 500 mg/m3 when using one filter, (2) – two filters
Source: developed by the authors

The conducted studies showed that when using a motorized filter respirator, there is a gradual increase in the resistance of the filter elements due to the accumulation of a layer of dust sediment, depending on the speed of rotation of the fan blades. Based on empirical dependences, the possibility of calculating the added resistance of the filter due to the accumulation of a layer of dust sediment was added to the simulation model, which affects the possibility of determining the term of protective action.

The developed structural diagram of the blower control facility allowed to select all the structural elements of the specified structural element of the motorized filter respirator (fan motor, electronic speed controller, number of filters), which allows ensuring prominent efficiency and modern technical level of individual respiratory devices per the international standards, which specify the requirements for the main indicators. Thus, the key element is protective efficiency, which is determined by maintaining all operational parameters of motorized filter respirators within the specified limits (pressure drop level no more than 370 Pa, flow rate no less than 115 l/min). A. Licina & A. Silvers (2021) discuss the necessity of its control through the equipping of such respirators with more advanced control systems that provide appropriate control over the protective effectiveness during operation. A newly developed software model of the movement of airflow through the air blower channels allows evaluating the impact on the protective properties of the respirator and the concentration of dust and changes in airflow through the filter elements due to the increase in filter resistance.

Furthermore, as noted by R. Weiss *et al.* (2021), it is essential to ensure the functionality of the motorized filter respirator so that its indicators also meet ergonomic requirements (breathing resistance, proportion of carbon dioxide and oxygen inhaled, dimensions of the face of half masks, viewing angles, speech intelligibility, etc.). Ensuring the mentioned requirements are implemented using the Arduino Uno R3 board, the LCD Keypad Shield module with a two-line display allows quickly processing input signals and maintaining the set parameters of the blower according to the physical load and dustiness of the air, air humidity, and ambient temperature. The obtained simulation results suggest that the developed device is characterized by considerably lower breathing resistance compared to known analogues described in the work of T. Vo *et al.* (2022). The refusal to use motorized filter respirators is noted due to profuse sweating and fogging of the sight glass. S. Wood *et al.* (2019) argue that in this regard, it is important to provide users with the ability to adjust the amount of air supplied to the mask to remove moisture, which can be implemented through the speed of rotation of the fan to obtain the desired value (at least 115 l/min), as well as through the possibility of adjusting the dimensions of each element of the design of the protective device, based on the requirements of the customers and equipped with an airflow control system, which, according to the design, should ensure the appropriate amount of air in the space under the mask.

Another critical indicator of a motorized filter respirator is the time of protective action under various loads, which is determined by the content of harmful impurities in the air atmosphere of the working area. D.E. McMahon *et al.* (2020) investigated that for this, the given scheme makes provision for the collection of signals from the relevant sensors, the information from which is processed based on the transfer function. In the future, the modes of movement of the airflow are determined, according to the change in the resistance of the filter, considering the accumulation of dust deposits and data from the environment: temperature and air humidity, which considerably affect the possibility of the filter functioning. According to K. Yamazaki *et al.* (2018), the duration of protective action also depends on the reliability of the motorized filter respirator to provide the required properties during a timed work shift. There is a need to test and control the charge of the battery, the discharge of which at a critical moment can impair the degree of user protection. Thus, M.Z. Chaari *et al.* (2020) devoted considerable attention to the development of a motorized respirator with a lightweight rechargeable battery to reduce the weight of IRP. However, a small charge of the battery led to a simplified control system, which provides only three modes of airflow, which leads to limitations in the use of such IRP, considering that the operation at high fan speeds also leads to a rapid discharge of the battery and stopping of air supply. Comparable conclusions were reached by O. Bazaluk *et al.* (2021), who recommended to abandon ventilators with a voltage of 12 V and switch to models powered by a voltage of 24 V. However, this requires an increase in the capacity of the battery, and therefore its weight, which will affect the performance of the user of the motorized filter respirator. There is a need to create a suitable algorithm for testing various modes of operation of a motorized filter respirator to establish clear time frames for its operation in diverse production conditions. In this regard, the development of a software model of the operation of a motorized filter respirator allows conducting the necessary experiments to investigate the effect of changing various parameters on the reliability of the IRP. Furthermore, the program allows reducing the time and costs of setting up the system in real operating conditions.

The promising nature of such developments is discussed by S. Sekoguchi *et al.* (2020), S. Sekoguchi *et al.* (2022). Adding a cooler to the blower design requires working out different airflow modes to ensure a suitable level of protection in heated professional environments.

CONCLUSIONS

The structural diagram of the control object was developed and all the structural elements of the blower of the motorized filter respirator were selected, which differs from the existing ones in that it uses a centralized fan for air supply, which has significantly better aerodynamic characteristics in terms of the airflow/pressure ratio, compared to axial ones fans. An experimental sample of the blower of a motorized filter respirator was developed, considering the functional relationships between the main variables (output adjustable variables, controlling effects and disturbances) and the restrictions imposed on them to ensure the control of the current state of operation and the term of protective action.

The modes of airflow were determined, according to the speed of rotation of the fan blade from the width of the PWM pulses, which depend on the resistance of the filter, the accumulation of dust deposits based on the transfer function. A software model of the blower of a motorized filter respirator was created, which allowed conducting a series of experiments to investigate the influence of dust concentration and changes in airflow through the filter elements on the value of the protective action period. It is proposed to ensure the effective functioning of a motorized filter respirator in the most adverse conditions. For this, it is necessary to use 2 filter elements to ensure a pressure drop level of no more than 370 Pa, a flow of air inhaled by the user of no less than 115 l/min during the entire work shift of six hours. In the perspective of further research, it is planned to work out the ACS mode in combination with a cooling device to reduce body temperature during production activities.

CONFLICT OF INTEREST

None.

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Удосконалення конструкції моторизованого фільтрувального респіратора

Анотація. Умови праці часто не відповідають нормативним вимогам щодо гігієнічних показників, зокрема виявляються порушення щодо наявності шкідливих домішок у повітрі робочої зони. В таких випадках, застосовуються моторизовані фільтрувальні респіратори для захисту органів дихання, які для ефективної роботи потребують розробки відповідної системи управління операційними показниками. Метою статті було удосконалення системи управління моторизованим фільтрувальним респіратором для підвищення захисної ефективності. Для створення відповідної системи управління застосовано структурно-параметричний синтез керування операційними показниками, на основі взаємозв'язків між основними змінними (вихідні регульовані змінні, керуючі впливу та обурення). Розроблено нову робочу схему об'єкту керування з підібраними конструктивними елементи повітродувки, основною відмінністю якої є використання плати "Arduino Uno R3" модуль "LCD Keypad Shield" з дворядковим дисплеєм для контролю режимів руху повітряного потоку, у відповідності до зміни опору фільтра з урахуванням накопичення пилового осаду на основі припущення, що передаточна функція з достатньою для практики точністю може бути представлена аперіодичною ланкою 1-го порядку. Для відпрацювання режимів роботи та визначення терміну захисної дії створена програмна модель роботи моторизованого фільтрувального респіратора, яка дозволила оцінити вплив концентрації пилу на зміну витрати повітря крізь фільтрувальні елементи з урахуванням накопичення пилового осаду на захисну ефективність. Розроблені рекомендації для забезпечення ефективного функціонування захисного пристрою згідно з вимогами при найбільш несприятливих умовах. Практичне значення полягає в тому, що завдяки удосконаленню системи управління моторизованим фільтрувальним респіратором забезпечується більш комфортний та ефективний захист, зокрема в умовах важких або шкідливих робочих середовищ

Ключові слова: вентилятор; тиск; швидкість обертання; концентрація пилу; повітряний потік; ширина імпульсів