

Development of a software and hardware system for monitoring the air cleaning process using a cyclone-separator

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Abstract. The article is devoted to the development of a hardware-software complex for monitoring and controlling the process of air purification by means of a cyclone-separator. The hardware of this complex is the Arduino platform, to which are connected pressure sensors, air velocities, dustmeters, which allow monitoring of the main parameters of the cyclone-separator. Also, a frequency converter was developed to regulate the rotation speed of an asynchronous motor necessary to correct the flow rate, the control signals of which come with Arduino. The program part of the complex is written in the form of a web application in the programming language JavaScript and inserts into CSS and HTML for the user interface. This program allows you to receive data from sensors, build dependencies in real time and control the speed of rotation of an asynchronous electric drive. The conducted experiment shows that the cleaning efficiency is 95-99.9%, while the airflow at the cyclone inlet is 16-18 m/s, and at the exit 50-70 m/s.

1. Introduction

The existing cyclones are being improved for more than 100 years. During this time, a great variety of structural forms of cyclones was determined. This circumstance testifies to the lack of a common opinion on the structural elements of the apparatus. A certain number of cyclones with a long cone and a small diameter work better than one large, which leads to a cyclone battery.

Cyclones are widely used in many industrial processes for various purposes, and to a large extent determine the ecology of industrial production. Industrial emissions are divided into technological and ventilation. Due to the imperfection of cyclonic cleaning (efficiency 70-90%), emissions lead to significant losses of products of the main production, and pollution of the atmosphere.

The theory and practice of cyclone construction determined the presence in the cyclones of the wall and axial helical flows moving in opposite directions. Modern methods of aeromechanics do not allow to predict an increase in the technological efficiency of cyclones with this organization of work.

2. Relevance

The Earth's atmosphere receives about 1 cubic meter per year. Km. Dust particles of artificial origin. At the same time, cyclone cleaning almost does not cope with the withdrawal of particles with a size of 1.0 to 10 μm from the process airflow, which determines the low efficiency most of all.

The regulatory and legal framework regulates the need and procedure for the use of gas purification facilities at sites that have a negative impact on the environment and is established by Federal laws: 1. "On Environmental Protection" of 10.01.2002 No. 7-FL; 2. from 04.05.1999 No. 96-FL "On



protection of atmospheric air"; And Resolution of the Government of the Russian Federation from September 13, 2016 No. 913 "On the rates of payment for the negative impact on the environment and additional coefficients."

According to article 8.21 of the Code of Administrative Offenses of the Russian Federation, the release of harmful substances into the atmospheric air or harmful physical effects on it without special permission shall be sanctioned by an administrative fine. Therefore, the development of new highly efficient methods of cyclonic air purification is very relevant.

3. Principle of operation

The very organization of the flow in countercurrent cyclones, when there is no clear boundary between the descending and ascending currents, which at the same time move with different velocities, does not allow achieving high efficiency of dust cleaning, especially for finely dispersed dusts.

To eliminate the drawbacks inherent in classical centrifugal cyclones, it is proposed to use an air-propeller cyclone for cleaning process air (figure 1), the design of which is protected by a patent [1].

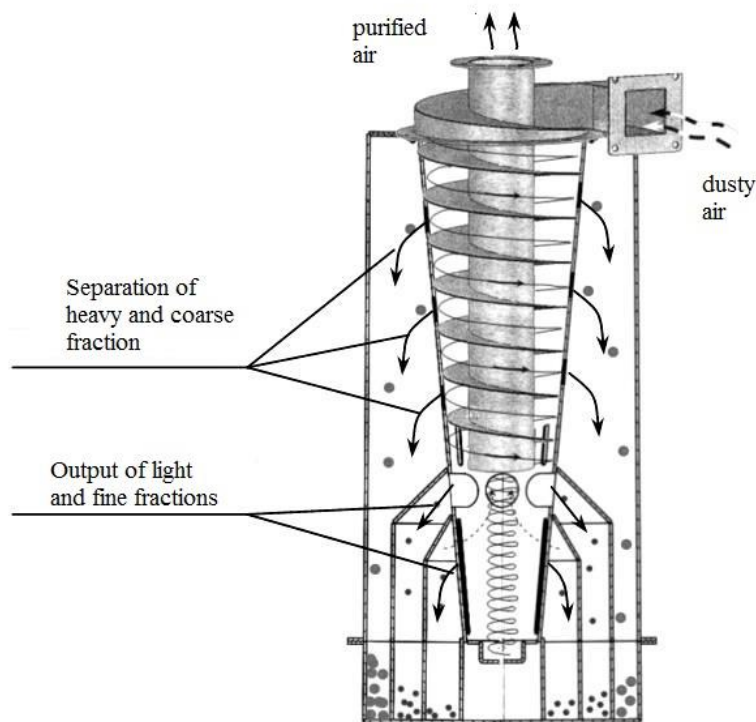


Figure 1. Aeronautical cyclone and the principle of its operation.

The main element of this cyclone is a conical screw insert located in a perforated truncated cone, which creates a limited space in the form of a screw channel with a decreasing cross-sectional area. At the same time, the exhaust pipe limits the interaction of the main stream containing dust particles and the counterflow - purified air. The design of the aerovoltaic cyclone also makes it possible to use it as a classifier, separating dispersed particles in accordance with their aerodynamic properties at various elevations.

The movement of the disperse flow in the aerovoltaic cyclone is due to the differential pressure ΔP , which creates a source of hydraulic energy (fan, blower, etc.). To study the processes of air movement in the developed cyclone separator, as well as the degree of airflow cleaning, it is necessary to develop a system for monitoring and controlling the cleaning process.

The monitoring and control system is being developed for the experimental cyclone separator developed at the Department "Machines and Apparatuses of Food Production" at AltSTU after I.I. Polzunov. This cyclone, simultaneously with air purification, can be used to divide dispersed materials

into fractions by a combination of physico-mechanical properties. In it, the efficiency of fractionating the products of grinding of particles from $240\ \mu\text{m}$ to $0.1\ \mu\text{m}$ with a real air cleaning factor up to 99.9% is improved. However, this installation is almost not automated, which makes it quite difficult to work with, so it became necessary to automate it [2, 3].

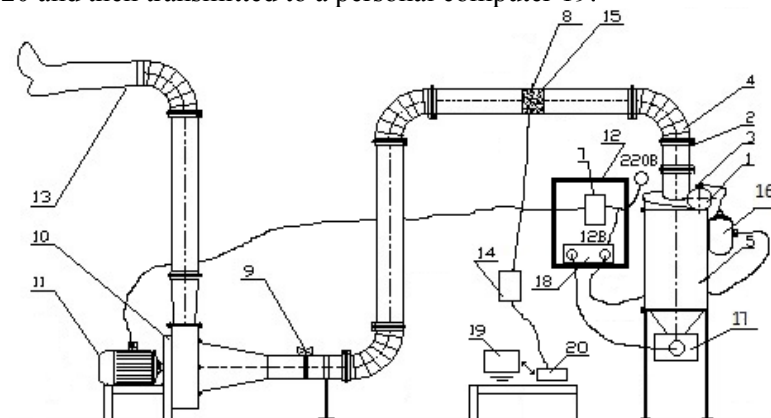
The principal difference between the proposed aerovoltaic cyclone and the classical version [7] is that due to the conical shape of the outer surface of the cyclone, the radius of the trajectory is reduced, along which dispersed particles move in the flow, and simultaneously the particle velocity increases due to the narrowing screw channel. By adjusting the number of turns of the screw insert, the pitch of the screw insert, the cross-sectional shape, it is possible to achieve the centrifugal effect necessary for separation of dust particles, including particles with a diameter of less than $10\ \mu\text{m}$. According to preliminary estimates, the proposed air-cylinder cyclone design can accelerate the flow to speeds of 50-60 m/s without exceeding the resistance of 1500 Pa, while achieving high efficiency.

The use of the screw motion of the air flow in a confuser with adjustable perforation is a case of steady motion, when in the whole mass of air the energy reserve is constant, i.e. The D. Bernoulli equation is applicable to the entire flow as a whole. This fundamentally distinguishes this approach from existing methods of separation of grinding products in uniform air and swirling air flows (cyclone installations).

The system consists of the following components (figure 2):

- 1) Experimental cyclone-separator.
- 2) Electric motor with fan for creating airflow.
- 3) Electric motor for controlling the dosing process of the product to be cleaned.
- 4) Sensors for monitoring system parameters.

The installation consists of a pipeline 1, a cyclone 5 and an air duct 15. The air receives movement from the fan 10. The electric motor of the fan 11 is connected to the network via a frequency converter 7 [6]. The product enters the material line from the receiving hopper 2 by a screw feeder 3, which is powered by an electric motor 4. At the end of the discharge line of the installation, a bag 13 is used to filter air. To measure the parameters in the air lines there are holes 8 into which measuring instruments and sensors are inserted. Parameters are measured using sensors 14. Sensor data is transferred to a data acquisition system 20 and then transmitted to a personal computer 19.



1 – pipeline; 2 – flange connection; 3 – feeder; 4 – branch; 5 – dust separator; 6 – discharge hopper; 7 – frequency converter; 8 – measuring openings; 9 – valve; 10 – fan; 11 – motor; 12 – control cabinet; 13 – filter bag; 14 – sensors for measurements; 15 – gasket; 16 – feeder motor; 17 – sluice motor; 18 – power supply; 19 – personal computer; 20 – sensor control system

Figure 2. The experimental cyclone-separator scheme.

4. Software and hardware

For the control, the following system parameters were chosen: air, amount of dust in the air, pressure and air temperature. These parameters will be monitored both at the inlet and outlet of the cyclone

separator. Also, the sensors of currents and voltages are connected to the system to control the parameters of the electric motor, they are installed in the windings of the electric motor. To track them, software will be written that allows you to track the data in real time, and save them for later processing. Moreover, the software will implement automation to control the fan speed in a wide range.

The general algorithm of operation is as follows (figure 3):

1. Arduino collects data from pressure, velocity, dust meter and main engine characteristics.
2. Arduino composes the data as a string and sends it to the server.
3. The server converts the string to a json object and sends the data to display to the client.
4. The client receives the data that is displayed for it in the interface.

In case the user wants to change the speed of the engine:

1. The desired speed is sent from the client to the server.
2. The server sends data to the Arduino microcontroller.
3. Arduino applies the received data and changing the parameters of the engine, thereby changing the speed of its operation.

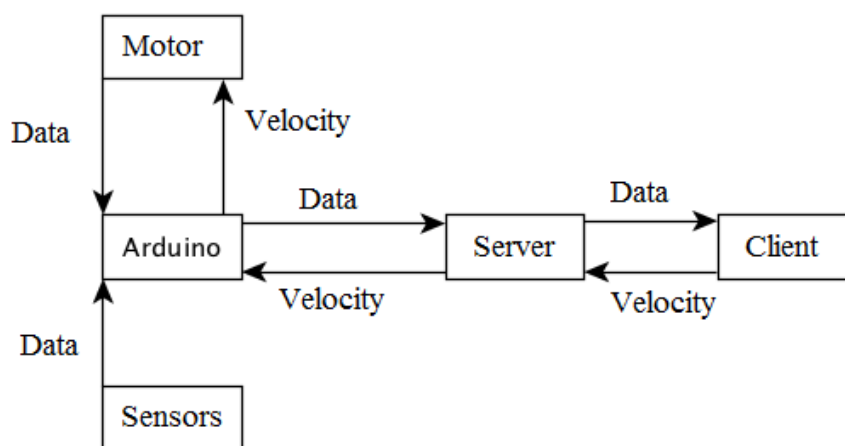


Figure 3. General work algorithm of application.

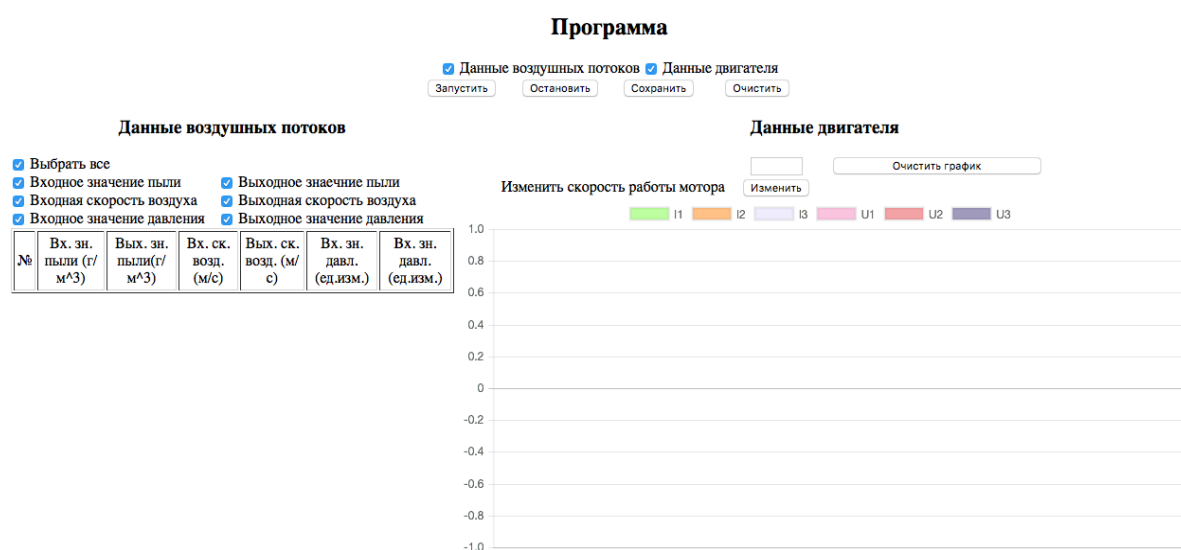


Figure 4. User interface.

The software consists of two programs: one written for the microcontroller Arduino, the second for the computer.

The program for the microcontroller is written in a c-like programming language, special for Arduino, and includes:

- data collection from six sensors;
- transfer of the received data to the of SI unit;
- collecting data of voltage and current from the motor;
- engine management;
- sending all received data to a computer application.

The program for the computer is written in the form of a web application in the JavaScript programming language and inserts into CSS and HTML for the user interface. The program is cross-platform and will work on most operating systems without any changes in the software. In order to run the program you need the NodeJS installed on your computer, for the first time you will also need to install additional modules necessary for running the program, this action is simple, because in the web application there is a special file for establishing dependencies independently in the command line. The software for the computer performs the following actions:

- obtaining data from the microcontroller;
- output data to the web application page;
- saving data to a text file;
- inform the microcontroller what speed the engine should have.

The program interface contains the following elements (figure 4):

- Data management with which the user can work. The user can use the checkboxes to select which data to display on the page. Until one of the options is selected, further actions are not possible.

- Block with buttons for program control. The start button allows you to start receiving data by the client, while this button is not pressed at least once, the other buttons are not active. The stop button allows you to stop the process of retrieving data, but does not erase them from memory. Thus, if you press the start button again, the new data will be written after the existing ones. The save button allows you to record all the received data in a text file, the data is formed in such a way that it can be later transferred to an excel file and made calculations there if necessary. The Clear button erases all currently received data.

- Block with air flow data (figure 5). Here, the data in the form of a table, obtained from wind and pressure sensors, dust meters, is displayed. A group of seven checkboxes allows you to select what data is currently required for the user to study. The table will automatically be rebuilt as requested by the user without reloading the page.

№	Вх. зн. пыли (г/ м ³)	Вых. зн. пыли (г/ м ³)	Вх. ск. возд. (м/с)	Вых. ск. возд. (м/ с)	Вх. зн. давл. (ед.изм.)	Вх. зн. давл. (ед.изм.)
2	2.418	2.498	4.576	1.608	7401.38	4901.54
3	0.884	3.441	1.945	7.431	6014.28	8828.75
4	2.428	1.851	8.19	3.176	3752.91	710.71
5	6.28	5.677	7.555	5.259	5730.56	4423.76
6	1.631	3.242	9.698	3.526	9193.02	4866.88
7	6.544	7.265	3.783	5.14	9935.98	5805.97
8	9.931	2.449	4.896	8.284	4679.07	3071.76
9	5.594	0.342	9.314	5.291	4061.58	9134.47
10	9.896	5.789	0.018	5.01	6507.5	2265.33
11	3.279	8.67	2.576	0.464	5497.02	2302.51

Figure 5. Table with data obtained from air flows.

- Block with data from the engine and control the speed of its operation (figure 6). Data from the engine are presented in the form of a graph. A block of labels at the top of the chart allows to choose which data to display at the moment. The control of the engine is very simple - the user enters the necessary speed in a special field and presses a button that will transfer data to Arduino, and she will make the necessary transformations to change the speed of work.

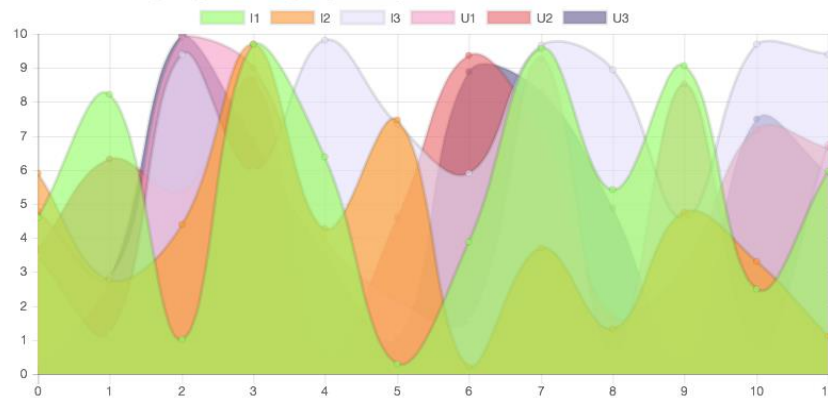


Figure 6. Graph with data obtained from an asynchronous motor.

The control of the asynchronous motor is carried out by means of a widely-adjustable transistor frequency converter for the AC motor by switching on or off the transistors in a certain sequence shown in figure 7, which provides vector-algorithmic switching of the motor windings and, accordingly, allows to regulate the engine speed [6].

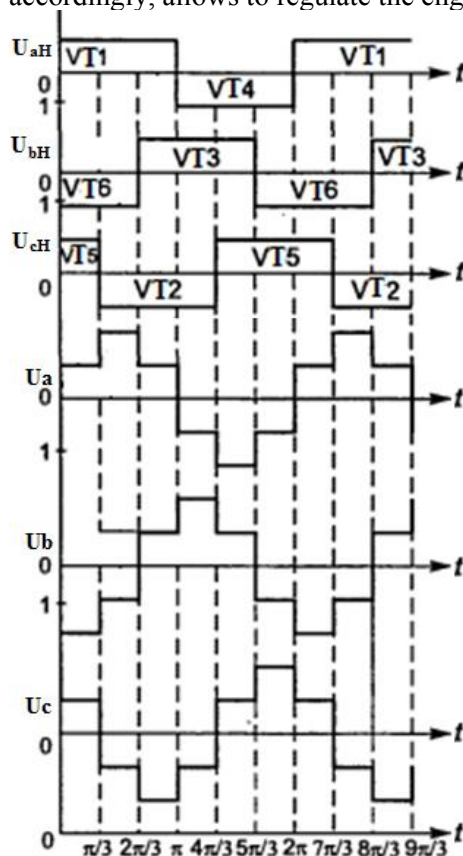


Figure 7. Work algorithm of a wide-range transistor frequency converter for an alternating current motor

5. Conclusion

The conducted laboratory tests using the hardware-software complex for the aerovoltaic cyclone-separator showed very satisfactory results both in terms of efficiency and aerodynamic resistance of the cyclone. On flour dusts, the efficiency of the cyclone-separator in question exceeded 99.5%, with an air flow rate of 376 m³/h, 472 m³/h and 516 m³/h, and ΔP less than 600 Pa. The velocity in the inlet branch of the screw insert was 18-20 m/s, at the exit of the screw insert the airflow velocity is 50-70 m/s.

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