DOI: 10.32347/2412-9933.2021.48.165-172

Chun Xiang Huang
Lecturer, *orcid.org/0000-0002-1483-5215*
Yancheng Polytechnic College, Institute of Intelligent Manufacturing, Yancheng, China
Liling Xia
Lecturer, *orcid.org/0000-0002-9245-854X*
Yancheng Polytechnic College, Institute of information and security, Yancheng, China
Ryzhkov Sergiy
DSc (Eng.), professor, *orcid.org/0000-0001-9560-2765*
Yancheng Polytechnic College,
International Academy of Marine Science, Technology and Innovation, Yancheng, China

DEVELOPMENT OF PHOTOCATALYTIC AND ULTRASONIC EQUIPMENT TO PREVENT THE SPREAD OF CORONAVIRUS SARS-COV-2. PHOTOCATALYTIC SAMPLE OF SEPARATION STAGE

Abstract. *The Full-scale experimental photocatalytic sample of separator consists of 5 equal purification modules. Each of the modules consists of separation elements for increasing of purification level. The equipment is designed for air volume G = 50… 150 m^3 / hour, should reduce the degree of microbial contamination of the air to the required level (capture particles of 0.1 μm) and help reduce the risk of airborne diseases. Project considers solving an important scientific and technical problem of creating and development of photocatalytic and ultrasonic heat and mass transfer separation equipment for air clean from dust and viruses (coronavirus SARS-COV-2). Filtration is a quite economical and efficient method of improving air-conditioning system, the air filtration systems represent a good solution for the improvement of Indoor Air Quality (IAQ), and the Antimicrobial treatments (coronavirus SARS-COV-2 prevention) of filters may be a solution to these problems. It is possible to prevent the accumulation and dispersion of microorganisms by adding anti-microbial agents on the surfaces of filter, which contributes to the improvement of air quality. Purification from dust and viruses and liquid media smaller than 1 μm requires development of air-purifying separation equipment able to capture particles of this size with implementation of resource-saving features base on photocatalytic and ultrasonic equipment. Development of photocatalytic and ultrasonic heat and mass transfer separation equipment for air clean from dust and viruses (coronavirus SARS-COV-2 prevention) is based on multilevel gradient aerosol technologies, as well as research of methods of their control, is their joint use in the presence of substantial gradients of the hydrodynamic and thermophysical parameters (temperature, pressure, velocity, density, etc.).*

Keywords: aerosol gradient technologies; separation equipment; gradient field; resource and environmental safety

Problem statement

The aim of the work is to develop photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2.

The equipment is designed for air volume G = 50… 150 m^3 / hour, should reduce the degree of microbial contamination of the air to the required level (capture particles of 0.1 μm) and help reduce the risk of airborne diseases.

Science project considers solving an important scientific and technical problem of creating and development of photocatalytic and ultrasonic heat and mass transfer separation equipment for air clean from dust and viruses (coronavirus SARS-COV-2).

The separation technologies and the devices employing them are able to perform purification from particles with the size exceeding 0.10 μm with the efficiency up to 99%.

Dust and liquid drops are the important medium for microorganisms and viruses to spread.

It is necessary to termly clean the components that are easy to be infected in air-conditioning systems (e.g., filter, heat exchanger and muffler) and to replace them in time in order to avoid the aggradations of pollutants. Moreover, the condensing water should be eliminated in time in air-conditioning systems to prevent bacteria from propagating.

Filtration is a quite economical and efficient method of improving air-conditioning system, the air filtration systems represent a good solution for the improvement of

Indoor Air Quality (IAQ), and the Antimicrobial treatments (coronavirus SARS-COV-2 prevention) of filters may be a solution to these problems.

It is possible to prevent the accumulation and dispersion of microorganisms by adding anti-microbial agents on the surfaces of filter, which contributes to the improvement of air quality.

Purification from dust and viruses and liquid media smaller than 1 μm requires development of air-purifying separation equipment able to capture particles of this size with implementation of resource-saving features base on photocatalytic and ultrasonic equipment.

Development of photocatalytic and ultrasonic heat and mass transfer separation equipment for air clean from dust and viruses (coronavirus SARS-COV-2 prevention) is based on multilevel gradient aerosol technologies, as well as research of methods of their control, is their joint use in the presence of substantial gradients of the hydrodynamic and thermophysical parameters (temperature, pressure, velocity, density, etc.).

All the conditions are met at purification of aerosol media in the gradient fields of temperature, acoustic oscillations, concentrations and pulsations when they pass through multifunctional surfaces able to separate and coagulate and to prevent coronavirus SARS-COV-2 spread.

Latest research and publications analysis

Over the last years some progress in the creation of technologies and production of purification equipment has been achieved. In this area there are some widely known studies by V. Strauss [1] S. Calvert and G.M. Inglund [2, 3], researchers of IAMSTI (Nikolaev), as well as by foreign researchers [4; 5].

These studies show the developed and used types of separation equipment. The presented analysis of the composition and aerosols characteristics [1 – 4], which is supplemented with new data, indicates that the particles have polydisperse composition (from less than 1 micrometer to large ones – more than 100 micrometers) and vapours.

This allows defining new methods of particle settling intensification on account of hydrodynamic forces. It also advantageous for the use of intensification of processes of particles transport to the deposition surfaces due to the velocity gradient fields, pulsation, pressure, temperature, acoustic vibrations for creating a compact separation equipment.

THE ARTICLE AIM is to develop aerosol gradient technologies (AGT) for separation equipment to present infectious safety of buildings from coronavirus SARS-COV-2. AGT is expected to use the gradient fields of speed, pulsation, temperature, pressure, acoustic vibrations.

Basic material

Basic mechanisms and physical processes of particles deposition in the aerosol technologies and quantitative need to analyze to develop photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2.

Physical processes of the above presented AGT can be characterized by the following processes of movement of medium that flows around the deposition surface: highly turbulent jets, turbophoretic, turbulent-diffusion, thermophoretic, acoustic, eddy and tear.

In addition, with the possible phases of the movement processes the processes of their interaction are possible – coagulation, grinding, heat and mass transfer.

The calculation of the flow of the separation equipment for AGT

On the basis of a mathematical model the calculation of photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2 was carried out, applying the possibilities for intensification of precipitation AGT.

The initial and boundary conditions were set according to the parameters of operation buildings ventilation and cleaning system.

The main objectives of the study are the following:

– analyze particle transfer processes in dispersed multiphase streams of power plants and identify promising ways to intensify purification processes due to inertia, acousticophoresis, turbophoresis, photocatalytic effects, non-isothermal gradient separation, etc. to prevent the spread of coronavirus SARS-COV-2;

– to develop a generalized mathematical model of separation processes of gradient aerosol technologies and to substantiate research methods;

– to develop circuit solutions of generalized multilevel gradient separation aerosol technologies;

– 3D-modeling on the basis of modern software packages and numerical calculation methods to investigate the patterns of particle transfer processes in dispersed multiphase streams and separation equipment;

– scientifically substantiate the creation of innovative cleaning technologies and devices that implement them for modern technologies for cleaning the air from dust and viruses to prevent the spread of coronavirus SARSCOV-2;

– prove the validity of the obtained scientific provisions for the intensification of air purification processes from dust and viruses to prevent the spread of coronavirus SARS-COV-2.

The study of photocatalytic and acoustic-phoretic levels of gradient aerosol technologies and obtaining circuit solutions for multifunctional deposition surfaces is planned. The structure of the flow will be investigated by thermogram filming.

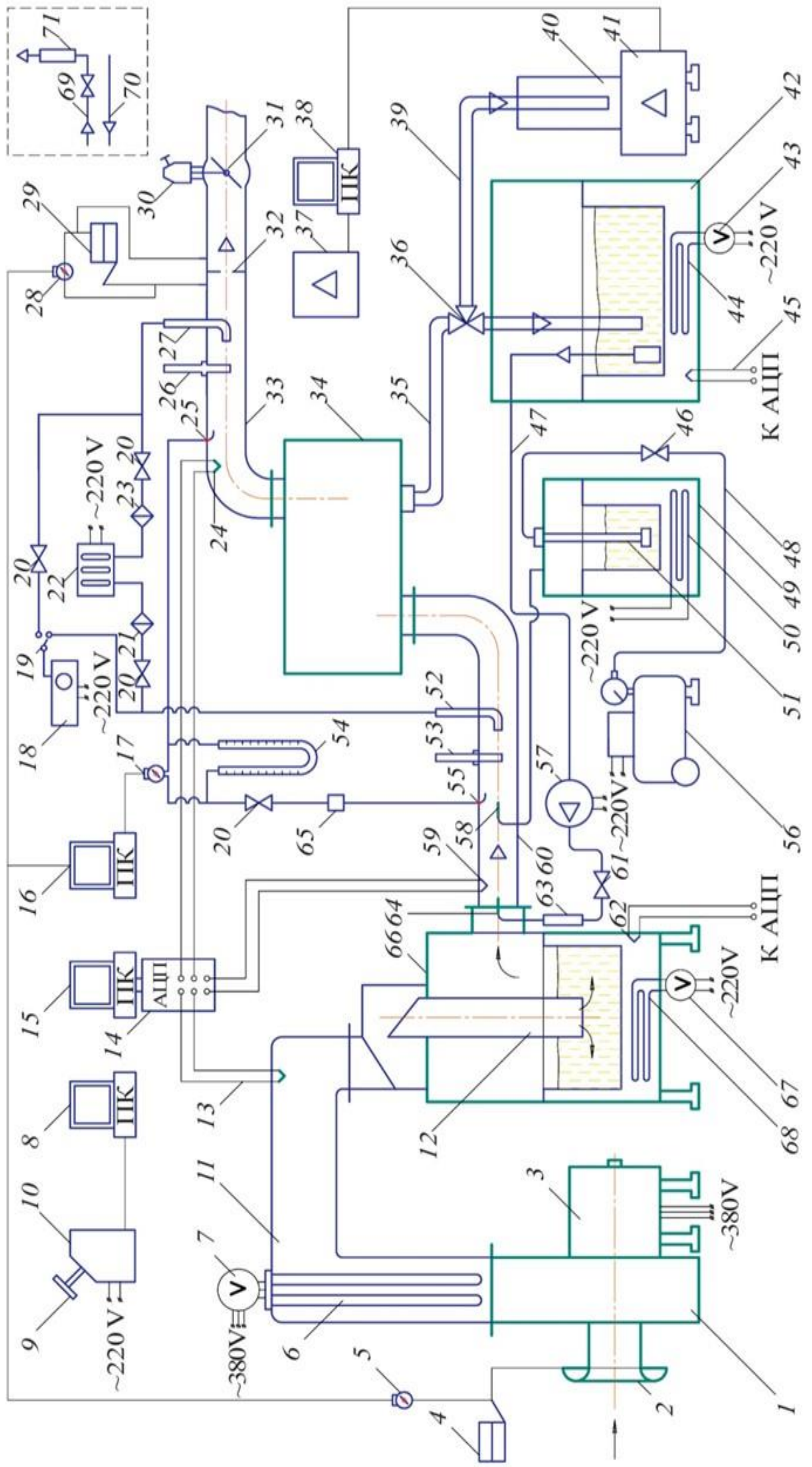

Figure 1 – Schematic diagram of the experimental stand

Increasing the flow rate at the inlet to the coagulator intensifies the deposition due to turbophoresis and inertia, and the thermal effect of non-isothermal gradient technology and diffusiophoresis decreases, and vice versa. Thus, the allowance due to the thermal effect to capture particles with a diameter of 0.1…1 μm at $u_{вх}$ = 9.5 m/s is about 40%, and at $u_{вх}$ = 13 m/s only 10%.

No influence of nonisothermality on the hydrodynamic characteristics of the flow in the grid coagulator and it is determined that the distribution of the main hydrodynamic characteristics of the flow (velocity, turbulence intensity, kinetic energy of turbulence, static pressure) is almost the same for the temperature difference 20…50° C and flow velocity 0.5… 7.0 m/s.

Calculation of multi-jet separator with AGT

The results of the calculation of the distribution of the longitudinal and transverse velocity component, static pressure, turbulent kinetic energy and the degree of turbulent energy dissipation in the separator are analysed.

The calculations confirmed the separation of the boundary layer to form the reverse currents (the field of negative values of the longitudinal velocity) and large amounts of vortex above the surface turbulent with significant energy potential.

Has been created experimental insulation for tests of separation for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2 (figure 1).

The equipment is designed for air volume G = 50… 150 m^3/hour, should reduce the degree of microbial contamination of the air to the required level (capture particles of 0.1 μm) and help reduce the risk of airborne diseases.

The separation technologies and the devices employing them are able to perform purification from particles with the size exceeding 0.10 μm with the efficiency up to 99%.

The measurements of venting system work flow area and proposed decision of its placement allows next geometrical dimensional parameters for Air Separator Turboimpact Filter.

Further designing process of photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2 needs usage of Multilevel complex scheme of intensification of separation processes using gradient turboimpact technologies.

Experimental stand for the follow-up of aerosol separators with an adjustable concentration of the fertile phase

The stand contains the following main elements: highpressure electric fan (blower) 1 with an electric motor 3; flow collector 2; cup micromanometers 4, 29; differential micromanometers digital 5, 17, 28; air electric heaters 6; autotransformers of alternating current 7, 43, 67; digital camera 9; digital microscope 10; air heating area 11; hot air distribution pipe and creating a foam layer 12; personal computers 8, 15, 16, 38; thermocouples 13, 24, 45, 59, 62; analog-to-digital converter (ADC) 14; photometric counter of aerosol particles 18; 19 – the switch for the counter; ball valves of the sample 20; allonge with analytical filters AFA 21, 23; aspirator 22; static pressure sampling probes 25, 55; inertial probes 26, 53; oil samplers 27, 52; adjustable solenoid valve 30; air flow control valve 31; flow washer 32; the original working measuring section 33; the investigated oil separator 34; oil drain pipe 35; three-way crane 36; analytical digital scales 37; oil supply pipeline in the measuring tank 39; measuring capacity 40; digital scales 41; butter tank 42; electric water heaters 44, 50, 68; ball valve for dosing compressed air 46; oil supply pipeline from the oil tank 47; compressed air supply pipe 48; a highly dispersed oil aerosol generator 49; the compressed air supply nozzle 51; micromanometer water U-shaped 54; compressed air electrocompressor 56; oil supply pump in the nozzle for generating coarse aerosol 57; highly dispersed aerosol supply tube 58; input working measuring section 60; ball valve oil dosing 61; rotameter for determining oil flow 63; nozzle for spraying coarse oil droplets 64; gravity separator of oil from air 65; the chamber of the first generator for the formation of high-temperature oil-air environment 66; the supply line 69 and the cooling coolant (water) 70 with taps 71 and a rotameter 72.

The stand is an open-type wind tunnel equipped with means of measurement, processing of results, as well as regulation and control.

The multiphase medium for the study is characterized by a polydisperse composition and contains highly dispersed particles with an equivalent diameter of less than 20 μm (including condensation origin less than 1 μm), coarse particles with an equivalent diameter of 20..500 μm and vapors.

The concentration of particles in the air was 0.5... 2.0 kg/m^3, ambient temperature up to 40°C. The high-pressure fan (blower) 1 takes the outside air through the flow collector (lemniscat) 2 and directs it for heating in the heating area 11, where the electric heaters 6.

In this area the air temperature rises to 10...40°C. The air flow rate is determined by the difference on the lemniscate 2 and the flow meter 32 using cup micromanometers 4 and 29, as well as differential digital micromanometers 5 and 29 connected to a personal computer 16.

The air flow rate is regulated by a valve 31 with a valve 30. A special generator 49 is used to generate significant concentrations of a highly dispersed aerosol with an average particle diameter of less than 2 μm. The highly dispersed aerosol generator allows to obtain particles with an average diameter of 0.3 μm and a concentration of up to 300 mg/m3.

The model two-phase high-temperature polydisperse medium is created by supplying to the inlet measuring section 60 of the aerosol from three generators: from the chamber 66, the nozzles 64 and the spray of the highly dispersed aerosol 58.

To assess the main parameters of the aerosol medium, there are appropriate measuring instruments. The temperature of the mixture is measured using a chromel-copel thermocouple 59, which is connected to a personal computer 15 to automate the processing of information via an analog-to-digital converter 14. In the measuring inlet area, all sensitive elements of the devices are located at a distance of at least three diameters of the pipeline from the intersection of the aerosol sprays.

Static pressure is measured by means of a spherical nozzle 55 or static pressure sampling holes on the walls of the pipeline (for dry purge mode), as well as a water micromanometer 54 or a differential digital micromanometer 17 connected to a personal computer 16. When selecting static pressure, an expanded tank 65 is provided.

The concentration of the aerosol was determined by passing the mixture, which is taken by the sampler 52, made in the form of a full pressure tube, through the analytical AFA filters located in the allonge 21. The measurement of air flow through the filter was carried out by the pressure drop across the measuring manifold 2.

Geometry of element of experimental sample of 5 blocs of equipment for air purification for infectious safety of buildseparation stages for photocatalytic and ultrasonic ings from coronavirus SARS-COV-2 is presented on Figure 2.

Experimental model of sample with 5 blocs of separation purification for infectious safety of buildings from coronastages for photocatalytic and ultrasonic equipment for air virus SARS-COV-2 is presented on Figure 3.

Operated experimental model of sample with 5 blocs of from coronavirus SARS-COV-2 is presented on Figure 4. Separation stages for photocatalytic and ultrasonic equip ment for air purification for infectious safety of buildings is presented on Figure 4.

On table 1-3 Research of separator efficiency G = 50…150 m/hour.

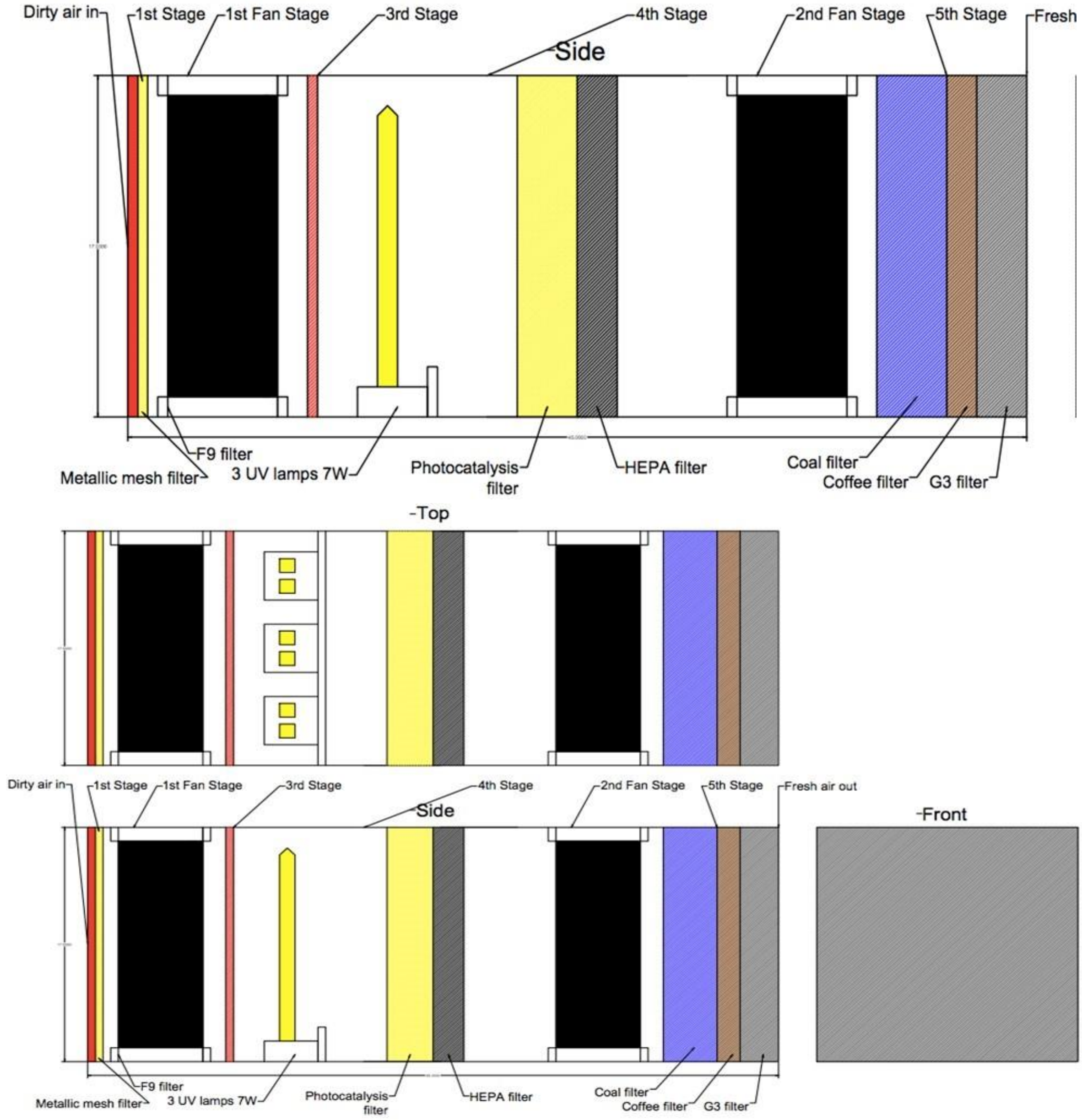

Figure 2 – Geometry of element of experimental sample of 5 blocs of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2

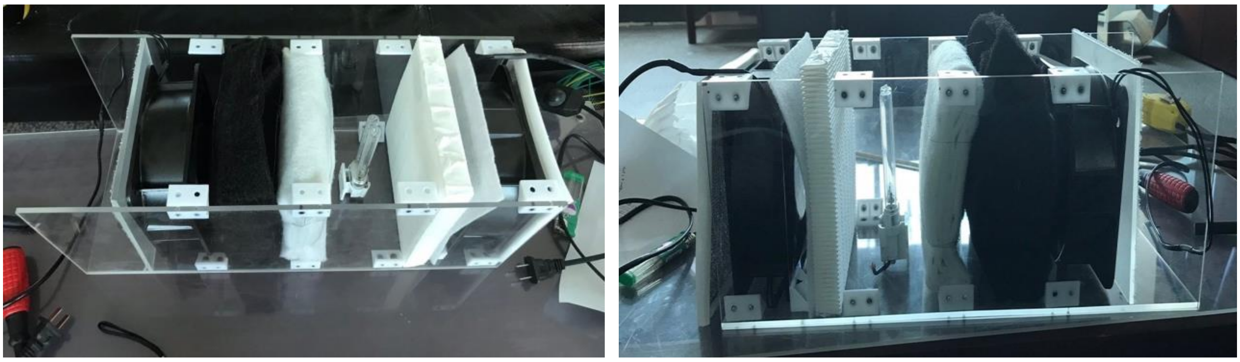

Figure 3 – Experimental model of sample with 5 blocs of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2

Figure 4 – Operated experimental model of sample with 5 blocs of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2

Table 1 – ***Research of separator efficiency G = 50…150 m³/hour***

Flow parameter						No pulsation			With pulsaton			
$G_п$, m³/hour	Tin, °C	C_{in}, gram/m³	d_{min}, мкм	d_{mid}, мкм	d_{max}, мкм	d_{min}, g_{out}, g/hour	d_{mid}, gout, g/hour	d_{max}, g_{out}, g/hour	d_{min}, g_{out}, g/hour	d_{mid}, g_{out}, g/hour	d_{max}, g_{out}, g/hour	ПСЕ, %
50	20	6	0.1	1	10	0.62	0.1	0	0.41	0.1	0	41,1
60						0.93			0.72			25,6
80						0.125		0.1	0.107			23,9
100						0.163		0.1	0.132	0	0.1	21,8
120						0.188		0.1	0.164	0.1		13,0
180						0.224	0.2		0.173	0.2		25,1
								Average				25,1

Table 2 – ***Research of separator efficiency G = 50 m³/hour***

$G_п$, m³/hour	T, °C	C_{in}, g/м³	η_Σ	$^\Delta P$, кПа	Cout, g/m³	Gout, g/hout	Cout, g/m³ ПСЕ	g_{out}, g/hour ПСЕ	ПСЕ
50	20	6	99,9	2,5	$70•10^{-3}$	7	$54•10^{-3}$	5,4	29,6
50					$83•10^{-3}$	8,3	$61•10^{-3}$	6,1	36,0
50					$75•10^{-3}$	7,5	$55•10^{-3}$	5,5	36,3
50					$83•10^{-3}$	8,3	$60•10^{-3}$	6,0	38,3
50					$78•10^{-3}$	7,8	$54•10^{-3}$	5,4	44,4
50					$84•10^{-3}$	8,4	$59•10^{-3}$	5,9	42,3
50					$75•10^{-3}$	7,5	$53•10^{-3}$	5,3	41,5
50					$78•10^{-3}$	7,8	$52•10^{-3}$	5,2	50,0
				Average	$78,25•10^{-3}$	7,825	$56•10^{-3}$	5,6	39,8

*Table 3 – **Research of separator efficiency G = 150 m³/hour***

$G_п$, m³/hour	T, °C	C_{in}, g/м³	$η_Σ$	$ΔP$, кПа	Cout, g/m³	Gout, g/hout	Cout, g/m³ ПСЕ	g_{out}, g/hour ПСЕ	ПСЕ
150	20	6	99,9	3.9	140•10⁻³	28,0	110•10⁻³	22,0	27,27273
150					144•10⁻³	28,8	114•10⁻³	22,8	26,31579
150					135•10⁻³	27,0	110•10⁻³	22,0	22,72727
150					139•10⁻³	27,8	108•10⁻³	21,6	28,7037
150					148•10⁻³	29,6	115•10⁻³	23,0	28,69565
150					142•10⁻³	28,4	113•10⁻³	22,6	25,66372
150					144•10⁻³	28,8	117•10⁻³	23,4	23,07692
150					138•10⁻³	27,6	110•10⁻³	22,0	25,45455
Average					141•10⁻³	28,2	112•10⁻³	22,4	25,98879

Generalized multilevel systems of photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2 have been developed, which are various options for combining the supply of aerosol medium to channels and surfaces for particle deposition due to forces of different nature: inertia, gradient forces – turbophoresis, acousticophoresis, non-isothermal gradient, turbulent diffusion and turbulent diffusion. Schematic solutions of multilevel gradient aerosol technologies based on the use of gradients of hydrodynamic and thermophysical parameters: temperature, pressure, velocity, density, etc. are developed.

On the basis of multilevel separation technology circuit solutions are developed: with levels of inertial and turbophoretic separation; with levels of inertial and nonisothermal gradient separations; with levels of inertial, non-isothermal and turbophoretic separations; with levels of inertial, turbo- and acousticophoretic separations; with levels of inertial, non-isothermal, turbo- and acousticophoretic separations; with levels of non-isothermal, turbo- and acousticophoretic separations.

Solving problems of intensification of purification processes in phase distribution in multiphase flows was performed by theoretical methods – physical models and methods of analogy in heat, mass and momentum transfer, equations of dynamics of force balance during particle motion and experimental methods on developed experimental stands – holographic interferometry, surface flow indication, high-speed photography, optical measurements of dispersion, particle concentration.

To study the separation characteristics of photocatalytic and acoustic phoretic technology in the multifunctional surfaces of the channels, a number of experimental separation equipment will be tested.

Preliminary Improving the efficiency of air purification from dust particles and viruses with the help of photocatalytic and ultrasonic equipment and integrated performance separation equipment is achieved by multilevel purification of aerosol media by combining different levels of gradient separation technologies with sequential or combined use of energy potential. separation) and external sources (non-isothermal and acoustic phoretic separation, photocatalytic separation).

The required level of air purification efficiency from dust particles and viruses depending on their operating modes is achieved by joint application of different levels of gradient separation technologies: inertial, turbophoretic, nonisothermal, acoustic phoretic and photocatalytic at gas velocities up to 20 m/s, particle sizes 0.1… 10 m also cleaning efficiency not less than 99%.

Conclusions

1. Purification from dust and viruses and liquid media smaller than 1 μm requires development of air-purifying separation equipment able to capture particles of this size with implementation of resource-saving features base on photocatalytic and ultrasonic equipment.
2. The Full-scale experimental photocatalytic sample of separator consists of 5 equal purification modules has been deevemoped. Each of the modules consists of separation elements for increasing of purification level.
3. The equipment is designed for air volume G = 50… 150 m³/hour, reduce the degree of microbial contamination of the air to the required level (capture particles of 0.1 μm) and help reduce the risk of airborne diseases.

References

1. Kalvert, S., Inglund, G. M. (1988). Atmosphere protection from industrial pollution: reference book, part 1. Moscow, Metallurgiya Publ., 760.

2. Kalvert, S., Inglund, G. M. (1988). Atmosphere protection from industrial pollution: reference book, part 2. Moscow, Metallurgiya Publ., 770.

3. Sazhin, T. M., Krechun, K. N., Botez, N. (2003). NOx and SO2 retention out of flue gases in electric fields. *International applied scientific journal*, 4, 193–196.

4. Straus, V. (1981). Industrial gas cleaning. Moscow, Khimiya Publ., 583.

5. Hall, D. E., King, D. B., Morgan, T. B. (1998). A review of recent literature investigating of the measurement of automotive particulate; the relationship with environment aerosol, air quality and health effect. *Ibid*, 982602, 53–65.

6. Ryzhkov, S. S. (2001). Ship complex installation of clearing oil mixture of water. *Proceedings of the third international conference on marine industry*, Varna, 2, pp. 285–288.

Received 28.10.2021

Чун Сян Хуан
Викладач, *orcid.org/0000-0002-1483-5215*
Політехнічний коледж Янчен, Інститут інтелектуального виробництва, Янчен, Китай
Лілінг Ся
Викладач, *orcid.org/0000-0002-9245-854X*
Політехнічний коледж Янчен, Інститут інформації та безпеки, Янчен, Китай
Рижков Сергій
Доктор технічних наук, професор, *orcid.org/0000-0001-9560-2765*
Політехнічний коледж Янчен, Міжнародна академія морських наук, технологій та інновацій, Янчен, Китай

РОЗРОБКА ФОТОКАТАЛІТИЧНОГО Й УЛЬТРАЗВУКОВОГО ОБЛАДНАННЯ ДЛЯ ЗАПОБІГАННЯ ПОШИРЕННЮ КОРОНАВІРУСУ SARS-COV-2. ФОТОКАТАЛІТИЧНИЙ ЗРАЗОК СТАДІЇ ПОДІЛУ

Анотація. *Натурний експериментальний фотокаталітичний зразок сепаратора складається з п'яти однакових модулів очищення. Кожен з модулів складається з розділових елементів для підвищення рівня очищення. Обладнання (розраховане на об'єм повітря G = 50…150 м³/год) повинно знизити ступінь мікробного забруднення повітря до необхідного рівня (вловлювати частинки 0,1 мкм) та сприяти зниженню ризику захворювань, що передаються повітряно-крапельним шляхом. Проєкт передбачає вирішення важливої науково-технічної проблеми створення та розроблення фотокаталітичного та ультразвукового тепломасообмінного обладнання для очищення повітря від пилу та вірусів (коронавірус SARS-COV-2). Фільтрація є доволі економним і ефективним методом покращення системи кондиціонування повітря, системи фільтрації повітря. Вона є добрим рішенням для покращення якості повітря в приміщенні (IAQ), а антимікробна обробка (профілактика коронавірусу SARS-COV-2) фільтрів може бути рішенням цих проблем. Попередити накопичення і розсіювання мікроорганізмів можна шляхом додавання на поверхні фільтра антимікробних засобів, що сприяє покращенню якості повітря. Очищення від пилу і вірусів та рідких середовищ розміром менше 1 мкм потребує розроблення повітроочисного сепараційного обладнання, здатного вловлювати частинки такого розміру з впровадженням ресурсозберігаючих функцій на основі фотокаталітичного та ультразвукового обладнання. Розробка фотокаталітичного й ультразвукового тепломасообмінного обладнання для очищення повітря від пилу і вірусів (профілактика коронавірусу SARS-COV-2) базується на багаторівневих градієнтних аерозольних технологіях, а також дослідженнях методів їх контролю. Це їх спільне використання за наявності значних градієнтів гідродинамічних і теплофізичних параметрів (температура, тиск, швидкість, щільність та ін.).*

Ключові слова: аерозольні градієнтні технології; сепараційне обладнання; градієнтне поле; ресурсна та екологічна безпека

Link to the article

APA Chun, Xiang, Huang, Liling, Xia & Ryzhkov, Sergiy. (2021). Development of photocatalytic and ultrasonic equipment to prevent the spread of coronavirus SARS-COV-2. Photocatalytic sample of separation stage. *Management of Development of Complex Systems*, 48, 165–172. dx.doi.org\10.32347/2412-9933.2021.48.165-172.

ДСТУ Чун Сян Хуан, Лілінг Ся, Рижков С. С. Розробка фотокаталітичного й ультразвукового обладнання для запобігання поширенню коронавірусу SARS-COV-2. Фотокаталітичний зразок стадії поділу. *Управління розвитком складних систем.* Київ, 2021. № 48. С. 165 – 172, dx.doi.org\10.32347/2412-9933.2021.48.165-172.