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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. EXPERIMENTAL SAMPLE OF SEPARATION STAGES

Abstract. *The aim of the work is to develop experimental sample of separation elements for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2. During the research and development work on creation of Experimental sample of air filter of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2 using turboimpact separation technologies, a working 3 dimensional model of geometry was created. 3D printing technologies were used to create Plastic model of experimental Sample. 3D model for 3D printer was created. The Full-scale metal experimental sample of Air Filter for air purification and oil and dust separation consists of 3 equal Purification modules. Each of the modules consists of 3 stages for experiments and increasing of purification level. The equipment is designed for air volume G = 50… 150 m3/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).*

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 m3 / 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.

Basic material

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. Increasing the flow rate at the inlet to the coagulator intensifies the deposition due to turbophoresis and inertia, and the thermal effect of nonisothermal 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 geometry of separation equipment (figure 1, 2) of separation stages for 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.

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:

- **length=665 mm**
- **height=200 mm**
- **depth= 85 mm**.

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.

During the research and development work on creation of Experimental sample of air filter of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2 using turboimpact separation technologies, a working 3 dimensional model of geometry was created (Figure 3).

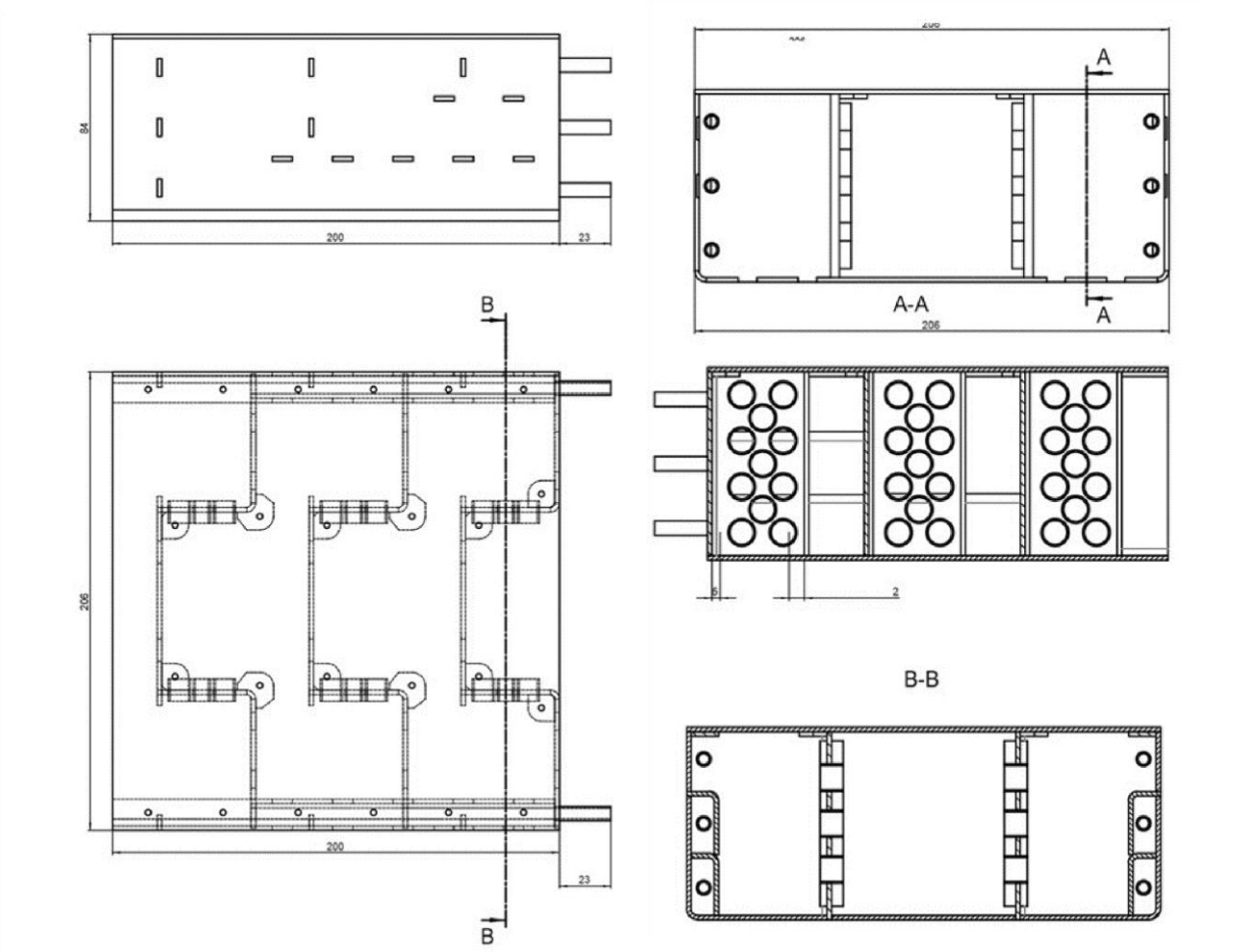


Figure 1 – Geometry of element of experimental sample of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2

During the research and development work on creation of separation technologies. 3D printing technologies were used Experimental sample of air filter for photocatalytic and ultra- to create Plastic model of experimental sample. 3D model for sonic equipment for air purification for infectious safety of 3D printer was Created (Figure 5). buildings from coronavirus SARS-COV-2 using turboimpact.

During the research and development work on creation of 2 using turboimpact separation technologies, full scale metal Experimental sample of air filter for separation stages for sample was assembled (Figure 4). photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2.

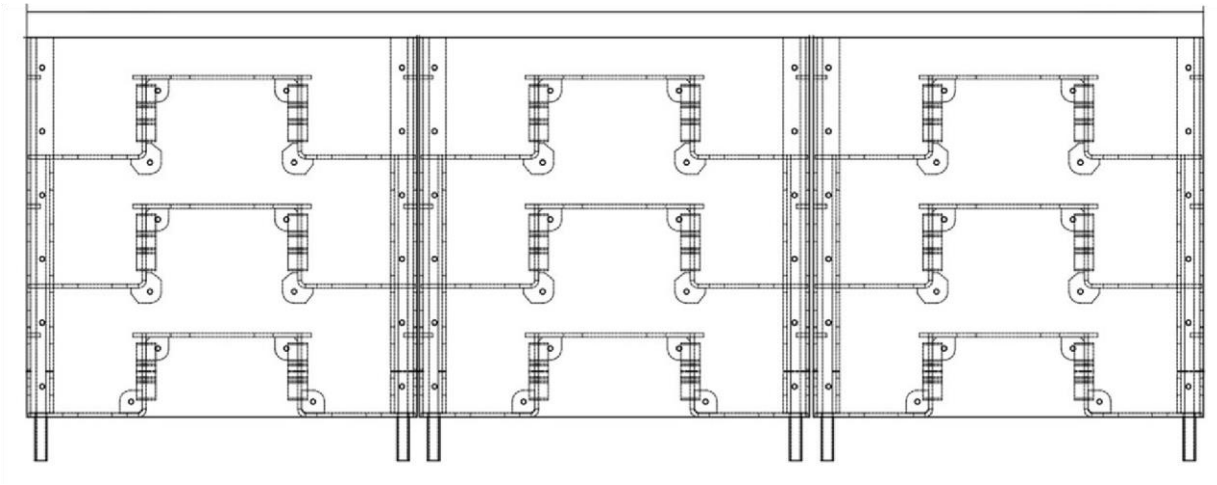
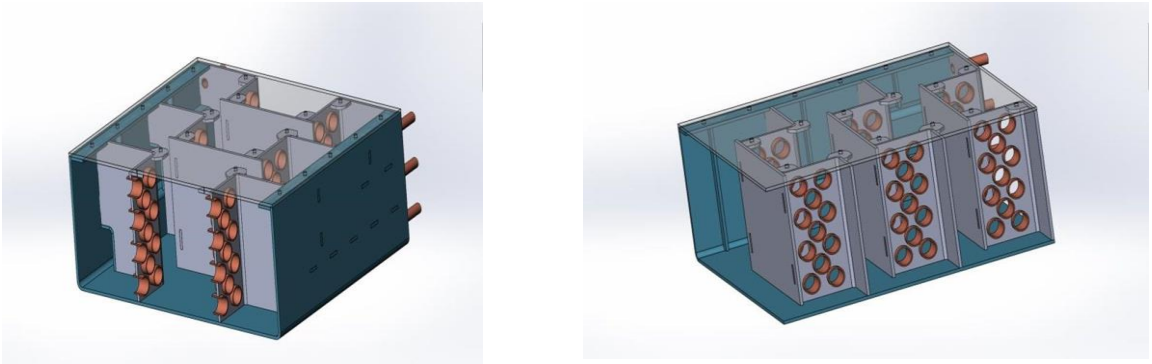
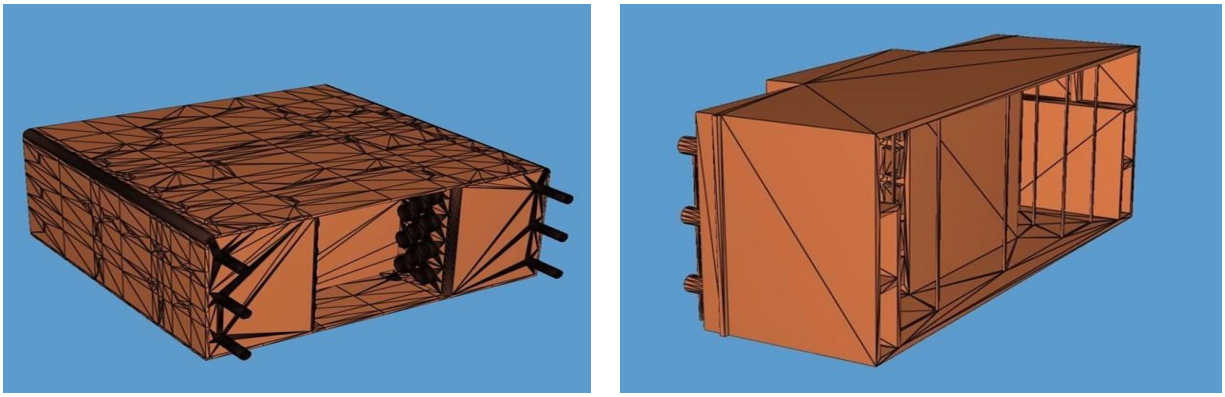


Figure 2 – Geometry of element of experimental sample of 3 blocs of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2



a *b*

Figure 3 – 3D-Geometry of element of experimental sample of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2: a – left view of working channel; b – right view of working channel



a *b*

Figure 4 – 3D Geometry of element of experimental sample of separation stages for 3D-printer procedure: a – left view of working channel; b – right view of working channel

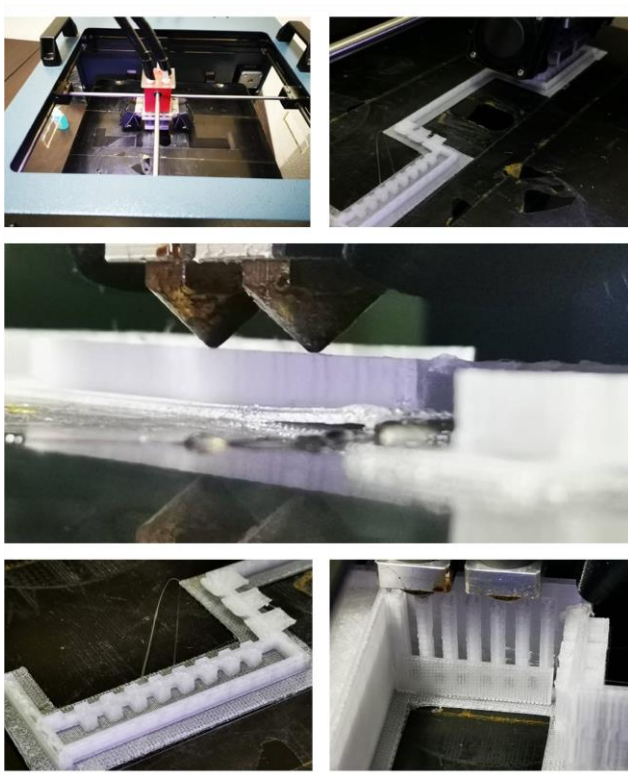


Figure 5 – 3D print of Geometry of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2

For creation of Coagulation module elements Corrugated Stage 1: Normal Coagulation module brass woven mesh of different sizes was used. Three stages of Stage 2: Improved Coagulation module Coagulation module were created (Figure 6): Stage 3: High efficiency Coagulation module.

Installed 3 Coagulation Modules into the Full-scale metal experimental sample of Air Filter for separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2. The construction of Metal experimental sample consists of tions of inside geometry for the experimental researches purification stages and allows to change different configure – (Figure 6, 7).

The Full-scale metal experimental sample of Air Filter for air purification and oil and dust separation consists of 3 equal Purification modules. Each of the modules consists of 3 stages for experiments and increasing of purification level:

– Inlet impact region.
– Coagulation module.
– Break rings unit.

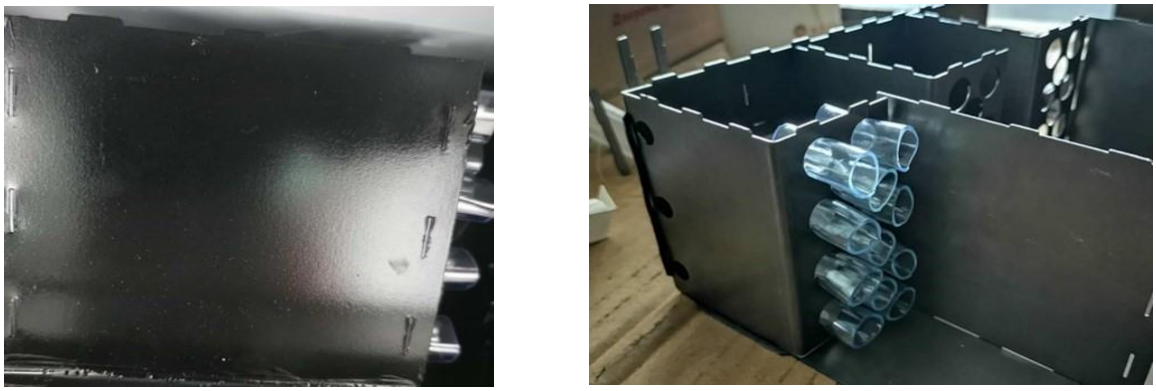
To study the separation characteristics of photocatalytic and acoustic phoretic technology in the multifunctional surfaces of the channels, a number of experimental separation equipment will be tested.

a *b* *c*

Figure 6 – Different types of Corrugated brass woven mesh used for creation of Coagulation modules of Full-scale metal experimental sample of Air Filter for air purification and oil and dust separation: a – hard mesh for Stage 1: Normal Coagulation module, b – medium mesh for Stage 2: Improved Coagulation module; c – small mesh for Stage 3: High efficiency Coagulation module

Figure 7 – Full-scale metal experimental sample of Air Filter for air purification and oil and dust separation without top case installed

The main construction decisions of each stage includes:



a *b*

Figure 8 – Elements of Full-scale metal experimental sample of Air Filter for air purification for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2: a – Inlet impact region, b – Break rings unit

Preliminary studies and calculations show that the transverse ripples significantly increase the value of the total capture coefficient in the speed range of 0.5 ... 5.0 m/s: from 15.0 to 46.3% at an initial flow rate of 0.5 m/s and from 48.7 to 66.7% at an initial flow rate of 5 m/s. Ultrasound is ineffective against highly dispersed aerosols and increases the value of the total capture coefficient (from 48.1 to 68.0%) with a particle diameter greater than 5 μm.

When particles of different sizes are deposited, which occurs at different oscillation frequencies, a higher frequency is required for smaller particles. The results of calculations show that at the frequency of ultrasonic oscillations at the level of 10 kHz, the sizes of the captured aerosol particles are in the range of 0.1 ... 5 μm. With increasing dispersion of aerosols, the use of ultrasonic waves in the separation cleaner is impractical.

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

Separation elements of photocatalytic and ultrasonic equipment (G = 50… 150 m3/hour) has been analyzed and proposed for use . It is designed to disinfect the air in a small area. Destruction of microorganisms in the air is carried out by repeated recirculation of air through a system of filters.

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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 ТА УЛЬТРАЗВУКОВОГО ОБЛАДНАННЯ ДЛЯ ЗАПОБІГАННЯ ПОШИРЕННЮ КОРОНАВІРУСУ SARS-COV-2. ЕКСПЕРИМЕНТАЛЬНИЙ ПРОТОТИП СТАДІЙ РОЗПАДУ

Анотація. *Метою роботи є розроблення експериментального зразка елементів розділення для фотокаталітичного та ультразвукового обладнання задля очищення повітря з метою інфекційної безпеки будівель від коронавірусу SARS-COV-2. Під час дослідження і розроблення експериментального зразка фільтра для повітря із сепараційними ступенями для фотокаталітичного та ультразвукового обладнання очищення повітря для інфекційної безпеки будівель від коронавірусу SARS-COV-2 з використанням технологій турбоударного поділу створено робочу тривимірну модель. Для створення пластикової моделі експериментального прототипу були використані технології 3D-друку. Розроблено 3D-модель для 3D-принтера. Повномасштабний металевий експериментальний зразок повітряного фільтра для очищення повітря та відокремлення олії і пилу складається з трьох однакових модулів очищення. Кожен з модулів складається з трьох ступенів очищення для експериментів і підвищення рівня очищення. Обладнання розраховане на об'єм повітря G = 50…150 м^3/год, що має знизити ступінь мікробного забруднення повітря до необхідного рівня (вловлювати частинки 0,1 мкм) і сприяти зниженню ризику захворювань, що передаються повітряно-крапельним шляхом. Проєкт передбачає вирішення важливої науково-технічної проблеми створення і розроблення фотокаталітичного та ультразвукового тепломасообмінного обладнання для очищення повітря від пилу та вірусів (коронавірус SARS-COV-2).*

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

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