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VORTEX-TYPE GRANULATION MACHINES: TECHNOLOGICAL BASIS OF CALCULATION AND IMPLEMENTATION ROADMAP

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Abstract: This work is devoted to describing the technological foundations and the main stages of calculating granulation machines with active hydrodynamic modes. The optimisation criterion is substantiated when choosing the design of the granulation machine. The work uses methods of analysis and synthesis, search for cause-and-effect relationships, theoretical and computer modelling, and experimental studies. The nodes of the vortex granulator directly influence the formation of a vortex fluidised bed, and the directional movement of granules of various sizes are determined. A technique for carrying out a computer simulation of the hydrodynamic operating conditions of a granulation machine in various operating modes with an assessment of the quality of granulated products (e.g., the production of porous ammonium nitrate) is proposed. The results of a computer simulation of the process of formation of a vortex fluidised bed are presented. A variant of the solution for developing an automation scheme for a vortex-type granulation machine is shown. A roadmap for introducing granulation technology in vortex-type granulation machines is described with details of the main stages. The prospects for improving the design of a vortex-type granulation machine and optimising the operation of a granulation plant to produce porous ammonium nitrate are outlined.

Key words: granulation machine, optimisation criterion, computer simulation, automation scheme, roadmap

1. INTRODUCTION

The production of granular products in various industries (chemical, pharmaceutical, food, mining, etc.) is implemented in various ways [1–3] in devices with several designs [4–7]. The choice of a method for obtaining a granulated product and the instrumentation of this process depend on the type of product, the productivity of the granulation plant, and the scientific justification for the use of one design solution or another [8]. Before starting production, a comparative analysis of methods and devices for granulation is carried out, which encompasses a computation of their technical and economic aspects, an assessment of the energy efficiency and environmental safety concerns involved, and ascertainment of the degree up to which the approach to granulation in question is in compliance with sustainable development goals.

One of the most versatile non-pressure granulation methods is implementing the process in a fluidised bed [9, 10] with a wide range of granulation devices [11]. Considering the effectiveness of such a hydrodynamic system in obtaining a wide range of granular products, fluidised bed granulators are a reliable solution for many industries. At the same time, it is necessary to constantly improve the design of granulators to stabilise the granulation process and create conditions for controlling the movement of granules in the working space of the device [12]. The second factor allows, with a high degree of accuracy, to calculate the residence time of the granules in the working space of the apparatus and, due to the variation in the design of the granulator, achieve optimisation according to the criterion 'minimum residence time of the granules in the device'.

One way to effectively control the directional movement of granules in the working space of the granulator is to use specific configurations of the fluidised bed. The vortex granulators [13] have shown their effectiveness and the ability to create a directional movement of the fluidised bed [14].

The use of fluidised bed granulators requires constant hardware design improvement and increased specific productivity. One of the methods of reducing the size of granulation equipment is to increase the relative velocity of the continuous and dispersed phases. This can be achieved by using vortex and highly turbulent flows in the devices of the suspended layer. The increase in productivity (phase load) for devices with such flow organisation leads to a smaller relative increase in their overall size and energy consumption for granulation.

Determination of the structure of the fluidised bed and hydrodynamic characteristics of the flow in vortex granulators, development of recommendations and methods of engineering calculation, and design of devices with predictable parameters taking into account the prospects for low-capacity and small-scale production of granular products and the implementation of new methods and equipment for granulation constitute an urgent scientific and practical task.

Creating a reliable calculation algorithm for vortex granulators is an essential step in their wide industrial implementation. It is possible to control the residence time of the granules in the working space of the vortex apparatus based on a description of the hydrodynamic conditions for the movement of flows [15]. The approach to the control process takes into account the technological characteristics of the process (the main characteristic is the velocity of the gas flow, which determines the range of stable existence of the fluidised bed), as well as the design features of the granulator, which determine the law of distribution of the gas flow velocity. This work aims to analyse the influence of the design of some nodes of the vortex granulator on the features of the movement of single-phase and two-phase flows.

2. DESCRIPTION OF THE VORTEX GRANULATOR'S DESIGN AND THE CONDITIONS FOR DESIGNING ITS INDIVIDUAL UNITS

The design of the vortex granulator is shown in Fig. 1. The principle of its action is as follows.

A heat transfer agent is fed through the pipe into the device in the lower cylindrical section of the granulator. It flows to the vortex gas-distributing unit. The heat transfer agent is twisted around the vertical axis of the device and acquires a spiral motion. The vortex axisymmetrical flow of the heat transfer agent moves up the inner cone space towards the material. Simultaneously the fluid material (solution or fusion) is fed into the formed vortex flow of the heat transfer agent through the pipe in the upper part of the outing case into the spray unit. The fusion jet flows out of the spraying unit and is broken into the spheric granules. The created granules make contact with the axisymmetric vortex flow of the heat transfer agent, become cool, are crystallised and come to the internal surface of the inner cone. Depending on the obtained size, granules are classified into large and small fractions due to the whirl and axis velocity changes in the axisymmetric vortex flow of the heat transfer agent, and these changes take place only as a function of the variation in the height of the inner cone. Small fraction granules are taken by the vortex flow of the heat transfer agent, move to the upper internal cone intersection and discharge from the active volume of the device through the annular space. In the annular space, the small fraction granules move down under the gravity force and get down to the lower intersection of the outing case. In the lower part of the outing case, these granules come to the depression zone. It is formed around the gas flow jet, which is fed through the pipe in the central part of the granulator (it is not shown on the scheme). Granules are picked up by this jet and thrown to the central part of the inner cone workspace into the vortex weighted layer core. The fusion that falls on the surface of the small granules is crystallised. Therefore, the size of the granules increases. The large fraction does not leave the device's workspace, and granules circulate in the inner cone and move along its intersection, as far as they are growing and increasing. When the intended size is achieved, granules fall on the surface of the inner cone, pass through the vortex gas-distributing unit and are output from the device. The spent heat transfer agent is driven from the inner cone through the proper pipe [16].

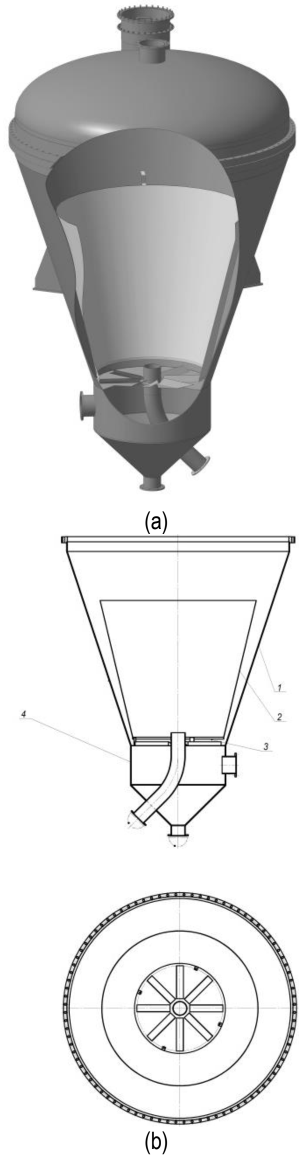
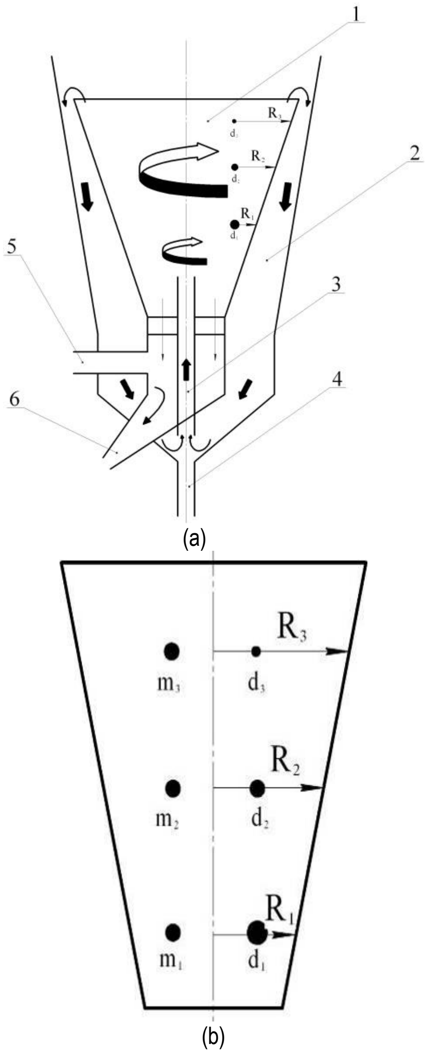


Fig. 1. The design of the vortex granulator (authors' elaboration): (a) schematic diagram (with cover and connectors); (b) elements of the workspace (granulation zone with cover and connectors); 1 – main body; 2 – inner case; 3 – gas flow distributor; 4 – swirler

A practical interest that the present research is concerned with is the nodes of the working space of the vortex granulator, which directly impact the distribution of the gas flow velocity in the apparatus. According to Yang [17], the range of stable existence of a fluidised bed is limited by two critical velocities:

- gas flow rate, which corresponds to the beginning of the fluidisation of the granules; and
- gas flow rate, which corresponds to the mode of entrainment of granules from the working space of the vortex granulator.

It should be noted that the vortex fluidised bed is a polydisperse system, and design solutions should be used in the working space of the vortex granulator, which will provide a different force effect on granules of various sizes. The simplest solution is to create a granulator with a variable cross-sectional area. Due to such a constructive solution, an efficient separation of granules into fractions is ensured (with the possibility of creating different heat treatment conditions for each fraction), as well as the movement of a specific fraction to the required point in the working space of the granulator. The scheme of the internal circulation of small granules (seeding agent) and the distribution of granules by size (classification) is shown in Fig. 2.



(a)

(b)

$R_1 > R_2 > R_3$

$m_1 > m_2 > m_3$

Fig. 2. Scheme of the working space of the vortex granulator (authors' elaboration): (a) organization of flows' motion (b) physical model of classification; 1 – zone of granulation and classification of granules; 2 – zone of internal circulation of the seeding agent; 3 – input of internal recycle; 4 – heat carrier for ejection; 5 – heat carrier for creating a vortex fluidised bed; 6 – withdrawal of commercial fraction granules; R_i – radius of granule; m_i – mass of granule

The distribution of fractions in the working space of the vortex granulator is significantly affected by the swirl mode of the gas flow and the degree of uniformity of the distribution of the gas flow under the swirler.

After the coolant passes through the supply pipe, it does not have time to be evenly distributed under the swirler; as a result of this, the coolant does not pass the entire cross-section of the swirler, and not all overclocking elements of the swirler take part in the vortex motion of the coolant. This causes uneven spiral motion of the granules, which causes uneven application of the film solution or melt.

This pattern/phase of the granules' motion is characterised/accompanied by the emergence of stagnant zones in the lower part of the working space (mainly on the periphery) and the lack of intense lateral mixing in the same part of the device. The presence of stagnant zones and the absence of lateral mixing lead to temperature inhomogeneities in the suspended layer, which reduce the uniformity of solid film formation from solution or melt on the granule surface and degrades the strength of the finished product and its monodispersity [16].

A constructive solution is proposed that allows the formation of a stable vortex gas flow (Fig. 3).

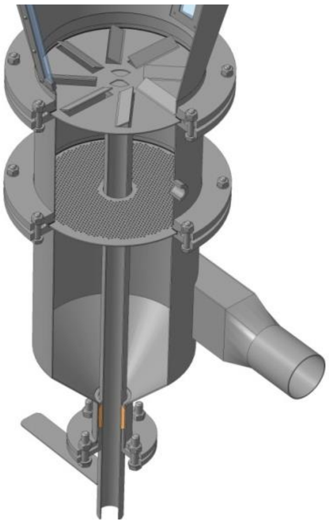


Fig. 3. The design of the swirler and gas flow distributor (authors' elaboration)

When installing the distribution element in the form of a failed perforated lattice in the middle part of the annular pellet trap, it becomes possible to redistribute the coolant throughout the cross-section of the annular pellet trap until it enters the vortex gas distribution unit. In this case, the coolant enters the vortex gas distribution node throughout its cross-section, reducing the likelihood of stagnant zones in the lower part of the working space and significantly intensifying the granules' lateral mixing. Reduction of stagnant zones and intensification of lateral mixing of granules lead to equalisation of temperature fields of the material in the suspended layer, which allows applying a film of solution or melt and granulation under the same thermodynamic conditions for all granules. On the other hand, the presence, in the design of the claimed device, of the distribution element in the form of a failed perforated lattice in the middle part of the annular pellet trap simplifies the removal of granules due to their uniform redistribution in the annular granules space.

This optimisation of the device for granulation in a fluidised bed reduces the equipment's size and energy consumption. It increases the degree of monodispersion of the particle size distribution of the resulting product [16].

3. COMPUTER SIMULATION OF THE PROCESS OF A VORTEX FLUIDISED BED FORMATION

Computer modelling has become a widespread means of studying the main processes and apparatuses of chemical production [18–20]. The use of computer simulation makes it possible to reduce the cost of experimental research and select the optimal equipment design before creating a scientific sample. Another advantage of computer simulation involves fixing the dynamics of changes in a particular parameter over time. Based on the choice of the optimal design of the nodes of the vortex granulator, computer simulation clearly shows the process of formation of the vortex fluidised bed. The distribution of granules in the working space of the vortex granulator, the intensity of the swirl of the gas flow (significant: evolution in time) and the presence of stagnant zones are determined by analysing computer simulation data.

The simulation of hydrodynamic processes in modern software products is based on the numerical solution of a system of equations that describe the most general case of the movement of a liquid medium. These are the Navier–Stokes and flow continuity equations [21].

Computer simulation of flow motion with the help of software products is based on the finite-volume method of solving the system of equations of the hydrodynamics of solid and dispersed phases and the use of a rectangular adaptive mesh with local grinding depending on the initial conditions for modelling.

Direct modelling of turbulent flows by numerically solving the Navier–Stokes equations written for instantaneous velocities is still complicated, and in addition, as a rule, not instantaneous but time-averaged values of velocities are of interest. Thus, the Reynolds equations are used for the analysis of turbulent flows instead of the Navier–Stokes equations.

Thus, computer simulation of the movement of single-phase and two-phase flows is based on solving the system of differential Reynolds equations and the continuity of the flow [21], and the system of differential equations of particle motion [22], considering the constraint of the flow of granules in a vortex fluidised bed. The modelling process consists of the following steps [21]:

- creation of a geometric (three-dimensional solid) model of the working area, where it is planned to study the hydrodynamics of flow movement;
- construction of the computational grid;
- choice of the mathematical model of calculation; and
- carrying out the calculation.

The dynamics of a vortex fluidised bed formation are shown in Fig. 4.

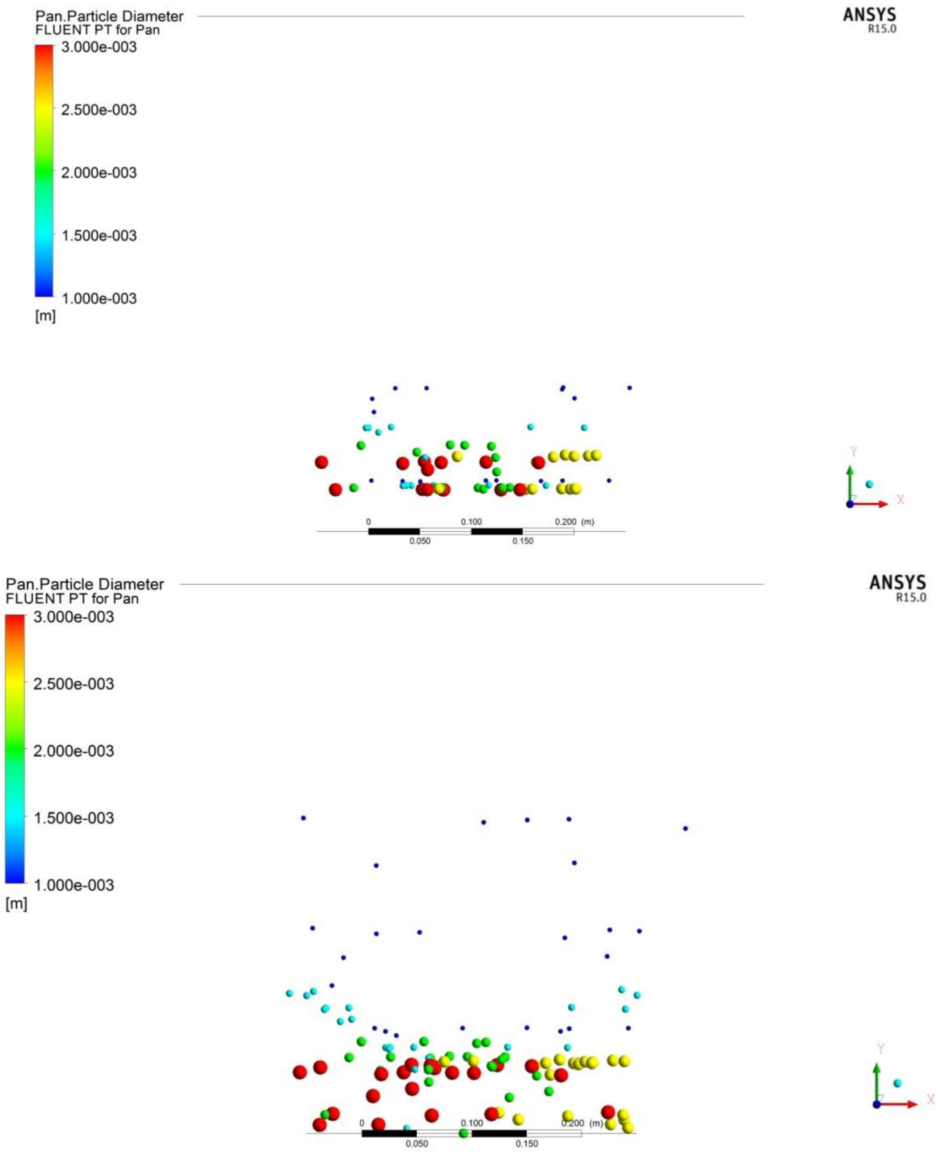


Fig. 4a. Dynamics of a vortex fluidised bed formation (authors' simulation results): formation of a vortex fluidised bed

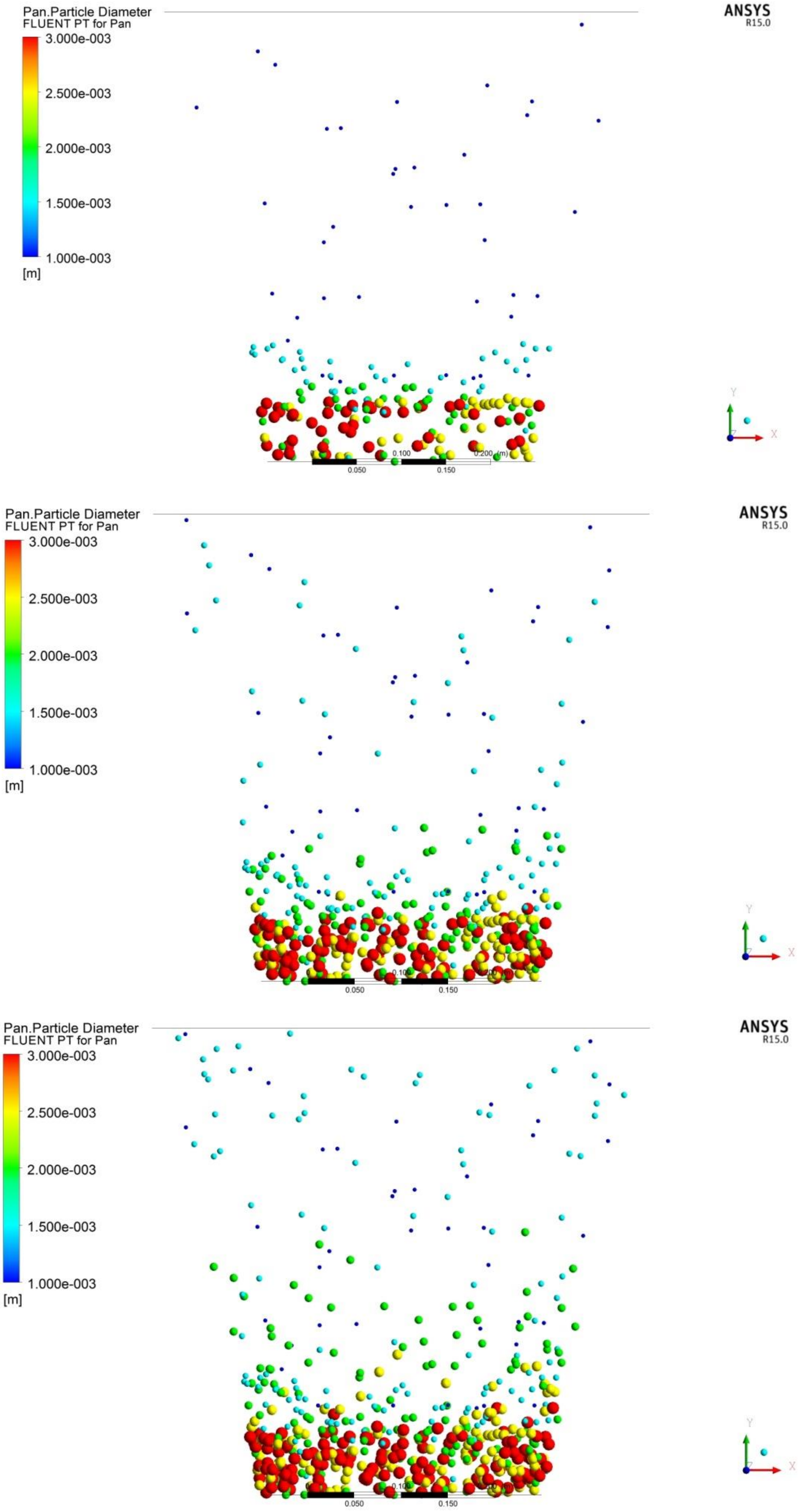


Fig. 4b. Dynamics of a vortex fluidised bed formation (authors' simulation results): creation of an 'active' zone above the gas distribution device

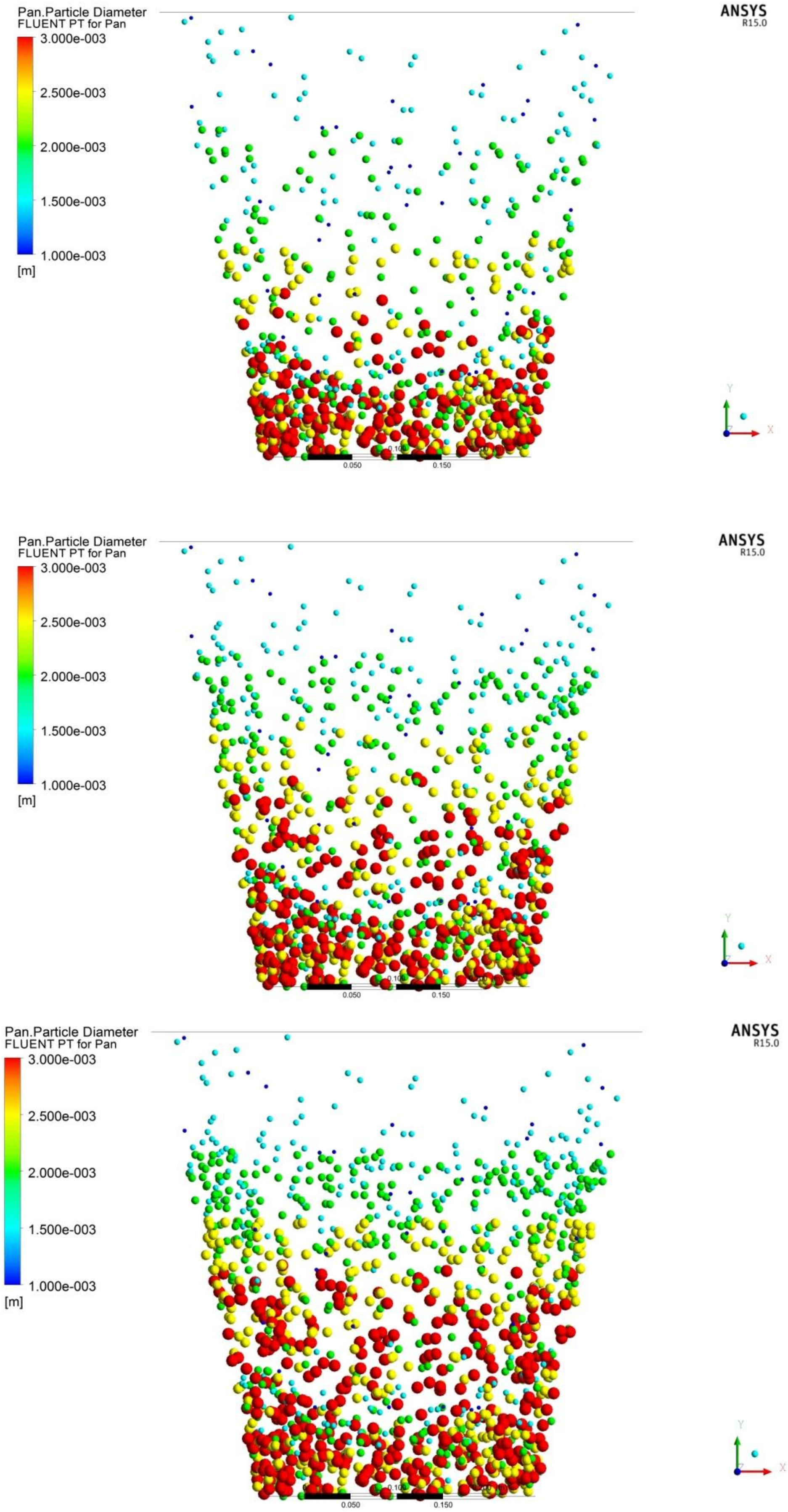


Fig. 4c. Dynamics of a vortex fluidised bed formation (authors' simulation results): developed vortex fluidised bed mode

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Analysis of simulation results allows the authors to draw the following conclusions:

- with an increasing degree of compression of the flow, there is a broader range of fractions at a certain height;
- with increasing degree of compression of the flow, the number of the main (corresponding to this calculated height) fraction increases; and
- the height of the vortex granulator decreases the content of the fraction from another range.

4. INDUSTRIAL IMPLEMENTATION OF THE RESULTS OF SIMULATION AND OPTIMISATION OF THE VORTEX GRANULATOR'S DESIGN

The process of introducing a vortex granulator based on the optimisation calculation of the design of its main units can be represented as the following algorithm, developed by the present authors:

- creation of a roadmap for the implementation of equipment;
- layout of the main components of the granulator;
- layout of the main equipment of the unit;
- development of a scheme for automated control of the unit; and
- product testing.

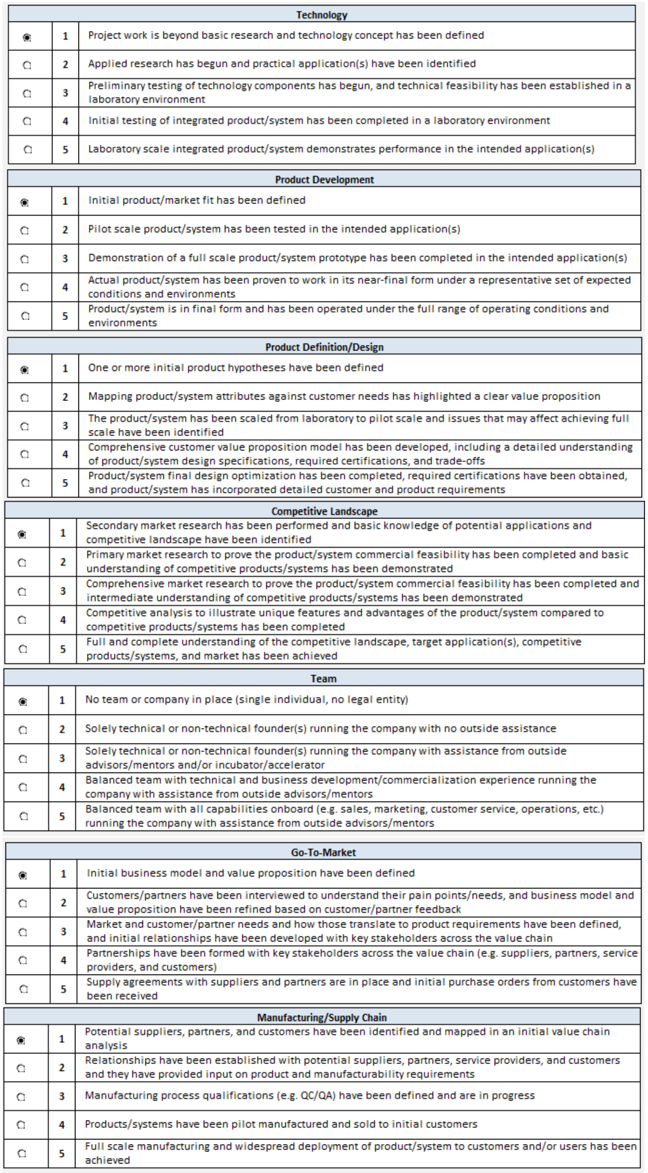
The vortex granulator implementation roadmap evaluates various aspects of a product's entry into the market. The use of the Technology & Commercialization Readiness Level Calculator [23] as an evaluation tool (Fig. 5 a) is suggested. Sequential selection of the development readiness level according to various criteria enables construction of the resulting analysis diagram (Fig. 5 b).

A set of activities is identified, which are intended to be carried out in the future to ensure that the desired level of readiness is achieved for each of the criteria. Below is an example of such activities for the criterion 'Product development'.

Their layout completes the choice of the design of individual nodes of the vortex granulator into a common assembly unit (Figs. 1 and 6). All corners and transitions between the nodes of the structure, where possible, are rounded, which gives a plastic and aesthetic appearance to the whole complex shape of the vortex granulator. The proportionality of each of the nodes of the vortex granulator infuses its appearance with integrity and conciseness. To ensure the correct functioning of the technological departure, it has been ensured that all units incorporate the minimum necessary requirements, are located in easily accessible places and do not interfere with the inspection and repair of industrial design.

When placing the equipment, it is necessary to consider the following technological requirements: ease of maintenance of the equipment and the possibility of dismantling the apparatus and its parts during repairs; ensuring the shortest pipelines between devices; a rational solution for in-plant transport. At the same time, building codes, requirements for natural light, rules and regulations on safety and labour protection, and sanitary and fire restrictions should be observed.

When choosing a layout option for technological equipment, it is necessary to consider the features of the technological process and the properties of the feedstock and the production product. The layout of the main technological equipment of the granulation plant is shown in the example of the production of porous ammonium nitrate (Fig. 7).



		Technology
●	1	Project work is beyond basic research and technology concept has been defined
○	2	Applied research has begun and practical application(s) have been identified
○	3	Preliminary testing of technology components has begun, and technical feasibility has been established in a laboratory environment
○	4	Initial testing of integrated product/system has been completed in a laboratory environment
○	5	Laboratory scale integrated product/system demonstrates performance in the intended application(s)

		Product Development
●	1	Initial product/market fit has been defined
○	2	Pilot scale product/system has been tested in the intended application(s)
○	3	Demonstration of a full scale product/system prototype has been completed in the intended application(s)
○	4	Actual product/system has been proven to work in its near-final form under a representative set of expected conditions and environments
○	5	Product/system is in final form and has been operated under the full range of operating conditions and environments

		Product Definition/Design
●	1	One or more initial product hypotheses have been defined
○	2	Mapping product/system attributes against customer needs has highlighted a clear value proposition
○	3	The product/system has been scaled from laboratory to pilot scale and issues that may affect achieving full scale have been identified
○	4	Comprehensive customer value proposition model has been developed, including a detailed understanding of product/system design specifications, required certifications, and trade-offs
○	5	Product/system final design optimization has been completed, required certifications have been obtained, and product/system has incorporated detailed customer and product requirements

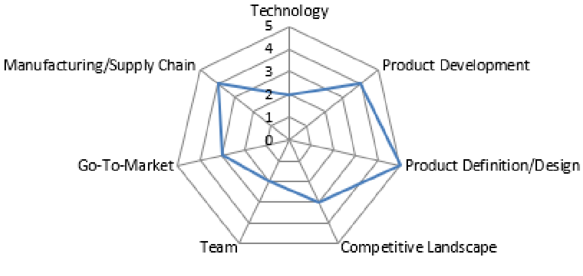
		Competitive Landscape
●	1	Secondary market research has been performed and basic knowledge of potential applications and competitive landscape have been identified
○	2	Primary market research to prove the product/system commercial feasibility has been completed and basic understanding of competitive products/systems has been demonstrated
○	3	Comprehensive market research to prove the product/system commercial feasibility has been completed and intermediate understanding of competitive products/systems has been demonstrated
○	4	Competitive analysis to illustrate unique features and advantages of the product/system compared to competitive products/systems has been completed
○	5	Full and complete understanding of the competitive landscape, target application(s), competitive products/systems, and market has been achieved

		Team
●	1	No team or company in place (single individual, no legal entity)
○	2	Solely technical or non-technical founder(s) running the company with no outside assistance
○	3	Solely technical or non-technical founder(s) running the company with assistance from outside advisors/mentors and/or incubator/accelerator
○	4	Balanced team with technical and business development/commercialization experience running the company with assistance from outside advisors/mentors
○	5	Balanced team with all capabilities onboard (e.g. sales, marketing, customer service, operations, etc.) running the company with assistance from outside advisors/mentors

		Go-To-Market
●	1	Initial business model and value proposition have been defined
○	2	Customers/partners have been interviewed to understand their pain points/needs, and business model and value proposition have been refined based on customer/partner feedback
○	3	Market and customer/partner needs and how those translate to product requirements have been defined, and initial relationships have been developed with key stakeholders across the value chain
○	4	Partnerships have been formed with key stakeholders across the value chain (e.g. suppliers, partners, service providers, and customers)
○	5	Supply agreements with suppliers and partners are in place and initial purchase orders from customers have been received

		Manufacturing/Supply Chain
●	1	Potential suppliers, partners, and customers have been identified and mapped in an initial value chain analysis
○	2	Relationships have been established with potential suppliers, partners, service providers, and customers and they have provided input on product and manufacturability requirements
○	3	Manufacturing process qualifications (e.g. QC/QA) have been defined and are in progress
○	4	Products/systems have been pilot manufactured and sold to initial customers
○	5	Full scale manufacturing and widespread deployment of product/system to customers and/or users has been achieved

(a)



(b)

Fig. 5. (a) Criteria for assessing the level of development readiness (authors' simulation results based on Technology & Commercialization Readiness Level Calculator); (b) Resulting analysis diagram: principal image, arbitrary choice of criteria level

During the layout of the equipment, several technological solutions were used [24], which were adapted by the authors for the conditions for the production of porous ammonium nitrate. Porous ammonium nitrate is highly hygroscopic (the ability to absorb moisture from the air), which is one of the reasons for its caking. The caking of ammonium nitrate is usually understood as the chemical losing its flow ability during storage. Due to its high hygroscopicity, pure ammonium nitrate is capable of caking during storage due to a significant change in its solubility and modification transformations with temperature changes. At the same time, the strength of the granules also decreases. Therefore, the main and auxiliary technological equipment for the granulation process will be placed indoors, which will ensure its isolation from the effects of precipitation. The absorption column for off-gas cleaning will be located in an open area, as the impact of atmospheric precipitation does not affect the conduct of the gas purification process. The open layout of the device will reduce capital costs for construction, improve conditions for the repair and installation of the column and reduce the impact of harmful and hazardous production factors (heat generation, explosion and fire hazard) on workers' plots.

To ensure the transportation of bulk materials without additional equipment and the creation of normal conditions for the cooling process of the obtained ammonium nitrate granules, the technological equipment will be located on two floors, one above the other.

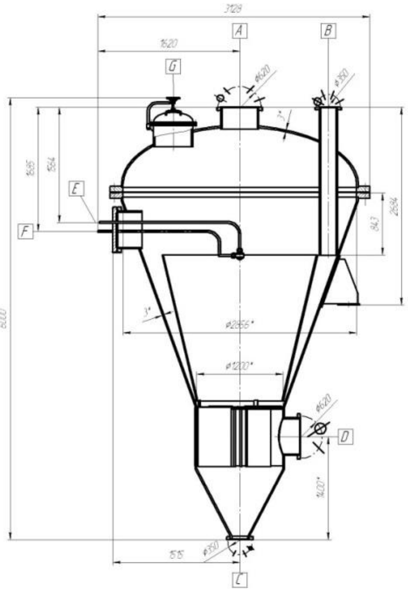
The building is designed as a rectangle. The main dimensions of the designed building are taken from the standard range of dimensions. The column spacing (location of centre axes) is 6 m, and the span width is 18 m. Thus, for the designed building, a grid of columns having dimensions of 18 m x 6 m was adopted. The height of the first floor is assumed to be 6 m, the second 4.8 m. For the organisation of inter-floor overlap, we accept standard prefabricated reinforced concrete beam ceilings consisting of crossbars and floor slabs. Standard floor slabs 6 m long are laid on crossbars. The beamed ceiling is laid on the shelves of the columns. The columns of the outer rows (wall) have one-sided consoles, and the middle rows have two-sided consoles for supporting the crossbars. In the extreme columns, embedded metal flights are provided for fastening walls and crossbars. Link columns have embedded metal flights for attaching crossbars. For the building being designed, we accept panel walls. The building is heated, and emergency heating is provided in case of plant shutdown. The panels are a flat single-layer structure for a heated building made of expanded clay concrete and perlite concrete. The panel thickness is given as 200 mm. Ordinary panels are designed for blind sections of walls; and lintel panels are installed above and below window openings.

The projected building provides for the installation of sagging equipment. It is installed not on the ceiling but on special beams. To do this, we use crossbars of the rectangular cross-section with a special selection. The main beams are laid on them. Auxiliary beams are installed on the main beams, on which a metal ring is laid. The device supports are stationed on this ring as the apparatus is being installed.

A service ladder with a span of 1 m and an inclination angle of 60° is installed on the second floor to service the technological equipment located on this floor. We make the flight of stairs from steel reinforcement and the landing of the stairs from sheet punched material.

To organise the covering of the designed building, we use reinforced concrete truss beams for a span of 18 m of a gable profile. The beams are attached to the columns with anchor bolts, released from the columns and supporting metal sheets, and welded to the embedded parts of the beams. Coating slabs made of reinforced concrete are laid directly on the truss structures (beams). To fasten the roof slabs to the rays, steel-embedded parts are provided for, at the end of whose longitudinal ribs the embedded parts of the slabs are positioned, and thereafter welded. The seams between the plates are sealed with cement-sand mortar. The composition of the enclosing part of the coating, which is laid on the slabs, includes a vapour barrier layer, a waterproofing layer and a layer of gravel embedded in the mastic that makes up the roof. The roof protects the coating, as well as the building as a whole, from moisture penetration. The floor construction is chemically resistant. The foundations of the designed building and equipment are reliably isolated from the action of aggressive environments.

A need was felt to attenuate the pressure that the blast waves (from the bulk chemical processes associated with ammonium nitrate processing) are expected to impose on the main building structures; accordingly, all buildings located in the industrial area were designed with windows larger than are usually necessary (for ensuring adequate ventilation and natural lighting); additionally, working platforms for the maintenance of technological equipment were partially covered with steel gratings.



Symbol	Function
A	Outlet of gas
B	Inlet of seeding agent
C	Outlet of granular product
D	Inlet of drying air
E	Air inlet for spraying of the liquid material
F	Inlet of melt
G	Hatch

Fig. 6. The industrial design of vortex granulator (authors' elaboration)

Fig. 7. Layout of the main equipment for the production of porous ammonium nitrate (authors' elaboration)

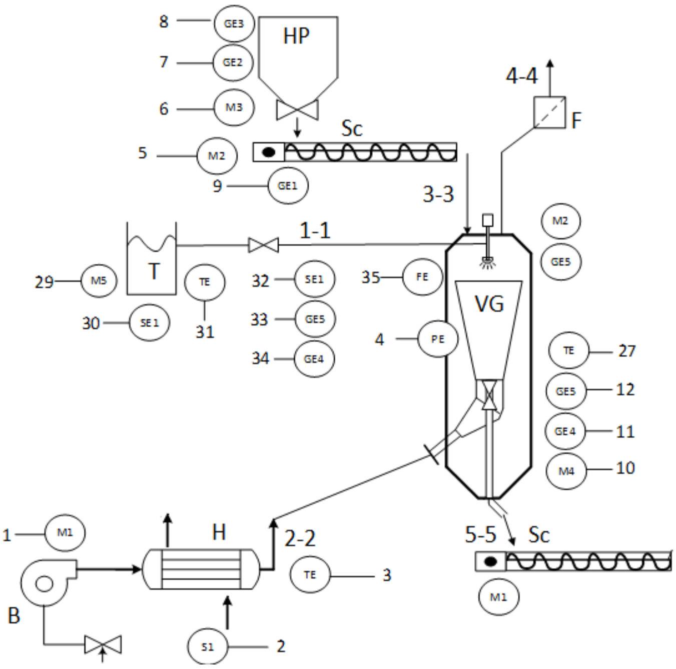
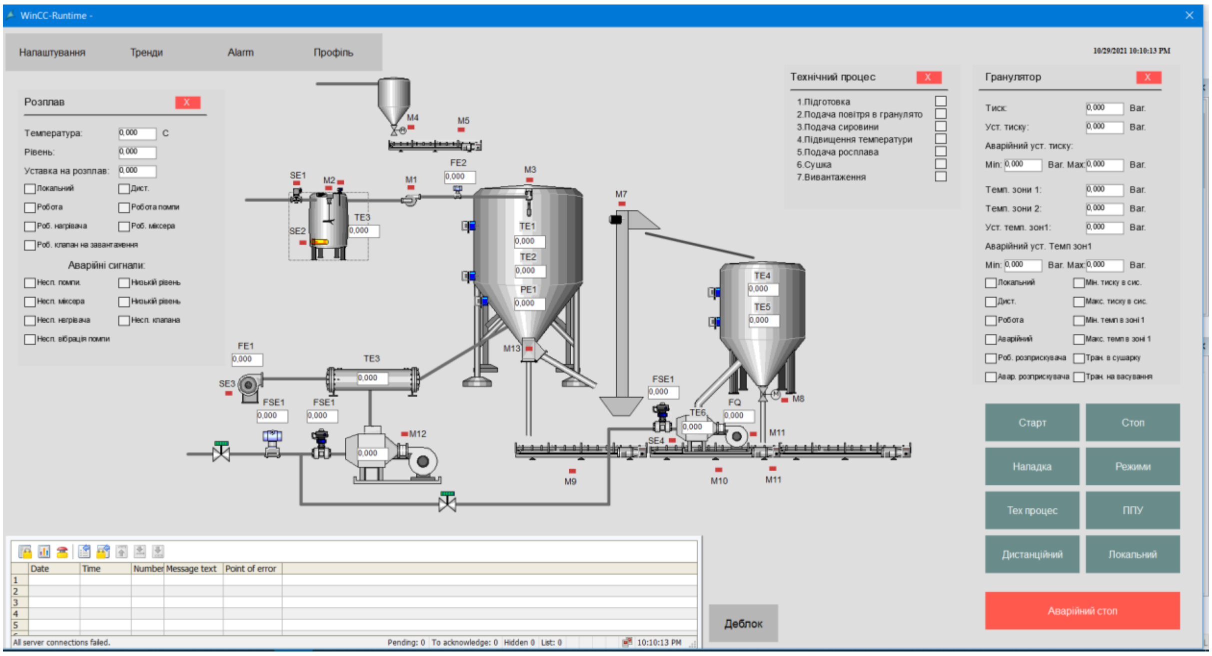


Fig. 8. Functional diagram of the control object (authors' elaboration)



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Розплав

Температура: 0,000 C
Рівень: 0,000
Уставка на розплав: 0,000
☐ Локальний ☐ Дист.
☐ Робота ☐ Робота помпи
☐ Роб. нагрівача ☐ Роб. міксера
☐ Роб. клапан на завантаження

Аварійні сигнали:
☐ Несп. помпи. ☐ Низький рівень
☐ Несп. міксера ☐ Низький рівень
☐ Несп. нагрівача ☐ Несп. клапана
☐ Несп. вібрація помпи

Технічний процес
1.Підготовка ☐
2.Подача повітря в гранулято ☐
3.Подача сировини ☐
4.Підвищення температури ☐
5.Подача росплава ☐
6.Сушка ☐
7.Вивантаження ☐

Гранулятор
Тиск: 0,000 Bar.
Уст. тиску: 0,000 Bar.
Аварійний уст. тиску:
Min: 0,000 Bar. Max: 0,000 Bar.
Темп. зони 1: 0,000 Bar.
Темп. зони 2: 0,000 Bar.
Уст. темп. зон1: 0,000 Bar.
Аварійний уст. Темп зон1
Min: 0,000 Bar. Max: 0,000 Bar.
☐ Локальний ☐ Мін. тиску в сис.
☐ Дист. ☐ Макс. тиску в сис.
☐ Робота ☐ Мін. темп в зоні 1
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Fig. 9. Dispatching system for vortex granulator control (authors' elaboration)

The dispatching system for controlling the vortex granulator (Fig. 8) based on Wincc (Fig. 9) was decomposed.

At the final stage of implementation, an analysis is made of the quality indicators of the finished product, namely porous ammonium nitrate. The product is evaluated with reference to the characteristics of the porous structure of the granule and the specific characteristics inherent in the ANFO (ammonium nitrate/fuel oil) industrial explosive component. An example of the structure of a porous ammonium nitrate granule is shown in Fig. 10.

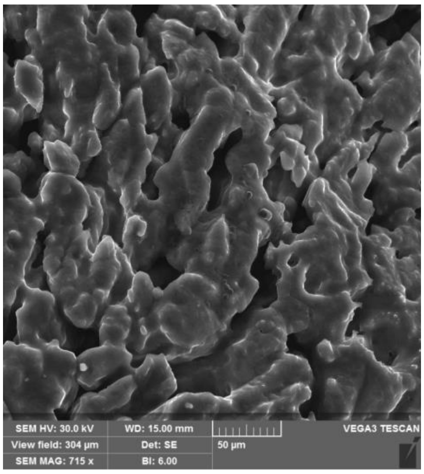

Fig. 10. Sample of porous ammonium nitrate granule (authors' photo based on the results of scanning electron microscopy)

5. CONCLUSIONS

Obtaining a consistent solution for tasks formulated for implementation via an optimised granulation function along the chain 'optimisation calculation of apparatus units – computer simulation – creation of a test sample of the granulator – installation equipment layout – provision of installation control – testing of the finished product' ensures a successful transfer of granulation technology using whirl granulators. The algorithm proposed in the present study can be applied to other equipment in engineering. Evaluation of the effectiveness of solutions at each stage of considering the level of developmental readiness for implementation allows the creation of a roadmap for the development of technology and improvement of the main equipment of the installation.

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