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Grinding closed circuit in centrifugal grinding unit

V S Sevostyanov, V I Uralskij, A V Uralskij, E V Sinitsa and L S Uralskaja

Belgorod State Technological University named after V.G.Shoukhov, 46, Kostyukov Str., Belgorod, 308012, Russia

E-mail: Alexx_1984.10@mail.ru; sinica.ev@bstu.ru

Abstract. The article presents scientific and technical developments on the creation of a technological module of a closed grinding circuit, the design of which allows improving the quality of the finished product, as well as improving the performance of the grinding unit. The process of organizing a closed cycle using a centrifugal air-through separator with two separation zones is described. The influence of the design parameters of the input and output elements of the pipes on the gas flow rate in the working chambers of the grinding unit using the SolidWorks software in the FlowSimulation module has been studied.

1. Introduction

One of the perspective ways to increase the efficiency of the grinding process can be the combination in one machine of the stages of course, thin and ultrafine grinding. Such combination can be determined not only by the shape and size of grinding bodies, but also by different trajectories of the motion of the chambers to provide appropriate modes of operation: for coarse grinding - intensive impact loading and partial abrasion; for fine grinding - impact load with increasing degree of abrasion; for ultrafine grinding - intensive abrasion [1,2].

A distinctive feature of the vibration-centrifugal grinding unit is the provision of the possibility of changing the regime of the dynamic action of grinding bodies on the crushed material, namely, the combination of impact and abrasive loads by providing the appropriate trajectories of grinding chamber motion.

Theoretical and experimental studies of centrifugal grinding units showed their efficiency for grinding materials with different physical and mechanical characteristics [3,4].

At the same time, the issue of increasing the degree of grinding of the material and, consequently, the quality of the finished product becomes obvious, which indicates the feasibility of further studies of the grinding units of the vibration-centrifugal type.

One of the options for improving the efficiency of the unit is the organization of the grinding process with closed circuit.

2. Development of the design of the grinding unit with closed grinding circuit

Several basic concepts of grinding in a closed circuit are usually considered for grinding in multi-chamber mills, each of which has certain disadvantages associated with insufficient grinding efficiency and high cost of equipment [5-7].

The developed design of a closed grinding circuit with the use of a centrifugal grinding unit eliminates these disadvantages [8].

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The technological module of the closed grinding cycle (Figure 1) contains a centrifugal grinding unit 1 with three grinding chambers, the top chamber of which is connected to the hopper 2 of the source material, and a centrifugal air-through separator 3 with two separation zones. The centrifugal grinding unit includes a frame 4, on which vertical cylindrical guides 5 are rigidly fixed with moving along them sliders 6. Support 7 in which the bearings and the eccentric shaft 8 are at both ends of the counterweights 9 are rigidly fixed on the base 4. The eccentric shaft 8 is connected to the frame 10 of a rectangular shape. The frame acts as a connecting rod in a crank-slider mechanism, formed from the base 4, eccentric shaft 8, frame 10 and sliders 6, to provide the necessary trajectory of the grinding chambers mounted on the frame. On the frame 10, the top 11, middle 12 and bottom 13 grinding chambers are horizontally fixed. Each grinding chamber contains grinding bodies corresponding to the type of grinding in the chamber.

At the ends of the grinding chambers, restrictive 14 and classification 15 grids are built in the direction of travel, respectively. At the output of the material from the top 11 and middle 12 grinding chambers, there are fixed fusers 16, and at the input of the material of the middle 12 and bottom 13 grinding chambers - diffusers 17. Restrictive grids 14 are designed to hold grinding bodies inside the grinding chamber, and classification grids 15 are designed to material classification. The presence of restrictive and classification grids provides a stable technological mode in each grinding chamber. Confusors 16 and diffusers 17 are tapered. The ducts 18 are connected to the confusor 16 by clamps, and the ducts 19 are connected to the diffusers 17 by clamps, which are connected to a centrifugal air-flow separator.

The centrifugal air-through separator 3 with two separation zones consists of a loading pipe 20, a discharge pipe 21 of coarse material, a discharge pipe 22 of a medium fraction material. The material separation zone is located above the loading pipe 20 and the discharge pipes 21 and 22. In the top part of the separation zone, radial blades 23 are placed. At the top of the centrifugal air-through separator there is the pipe for the output of the gas-material mixture 24.

The separator loading pipe 20 is connected to the top 11 and middle 12 chambers of the grinding unit through the ducts 18, and with the bottom chamber 13 through the duct 18, which is attached to the outlet nozzle of the grinding unit. The discharge pipe 21 of coarse grinding of the separator is connected to the middle grinding chamber 12 by means of a flue 19. The discharge pipe 22 of the middle fraction of the separator is connected to the bottom chamber 13 by a flue 19.

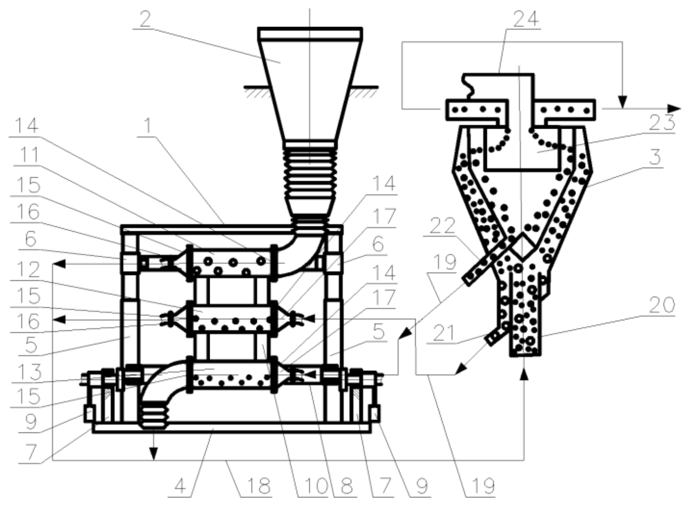

Figure 1. Technological module of the closed grinding circuit.

The method of a closed grinding circuit using a centrifugal grinding unit with three grinding chambers is as follows.

The source material from the hopper 2 is continuously fed into the loading pipe of the centrifugal grinding unit 1 and then through the restrictive grate 14 enters the top grinding chamber 11, in which coarse grinding of the source material is ensured.

The air flow generated by the fan (not shown in the figure), the grinding material moves along the chamber, passes through the classification grid 15, the confusor 16, and through the duct 18 enters the loading pipe 20 of the centrifugal air-through separator 3.

In the separator in the separation zone due to the twisting of the gas-material flow by radial blades 23, the material is separated under the action of centrifugal forces in combination with the forces of gravity of particles of different mass on the coarse fraction material, the medium fraction material and the fine fraction material.

The coarse fraction material from the discharge pipe 21 through the duct 19 through the diffuser 17 and the restrictive grid 14 enters the middle grinding chamber 12, which moves along an elliptical path and provides the grinding of the source material to the middle fraction. Then, due to the air flow, the crushed material passes through the classification grill 15 and the confusor 16 into the gas duct 18 and further into the loading pipe of the separator 20.

The material of the middle fraction moves from the discharge pipe 22 through the duct 19 through the diffuser 17 and the restrictive grating 14, enters the bottom grinding chamber 13, moving along a circular path, which provides fine grinding of the source material. Due to the air flow, the grinded material enters the gas duct and then the separator loading pipe.

The grinded material of the fine fraction (finished product) with the gas stream rises upwards, and through the pipe 24 of the gas-material mixture it enters the further processing of the gas stream to the cyclone for air purification from particles. The grinding process is carried out in continuous mode.

The material passes through three stages of grinding with different modes of operation in one mill with three grinding chambers. At the same time, after each grinding chamber, a classification in a centrifugal air-pass separator is carried out. This gives a greater guarantee of the uniform dispersion of the material, which is achieved by ensuring continuous output of the finished product at various stages of the process and returning the undersized material to further grinding to the state of the finished product.

In addition, to reduce the energy consumption associated with the movement of the gas flow in the grinding chambers of the unit, it is necessary to establish rational design parameters of the input and output pipes of the grinding chambers, which reduce the resistance of the flow and at the same time create turbulence in the chambers necessary for mixing material.

Structurally the loading pipes of the chambers are made in the form of expanding truncated cones - diffusers, the discharge pipes – in the form of tapering truncated cones – confusors [9,10]. Using diffusers and confuser with different parameters the speed of the gas flow can be changed, thereby changing the grinding efficiency.

3. Experimental studies

To study the influence of the design parameters of the pipes, the SolidWorks FlowSimulation module software which allows the calculation of the gas (air) flows in the grinding chambers was used. For the calculation, Model of a grinding chamber in actual dimensions was selected (Figure 2). It containing a cylindrical body 1, restrictive grids 2, inlets 3 and outlet 4 for the gas flow. For the calculations, the pipes of inlet 3 and outlet 4 were used, respectively, with diffusers and convergers with taper α = 20 °, 30 °, 45 ° and 90 °.

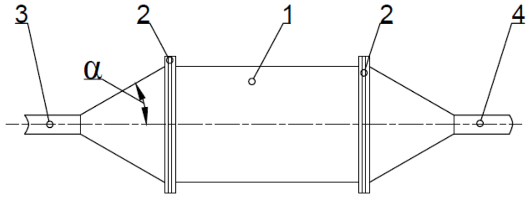

Figure 2. Grinding chamber scheme.

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The results of the calculations are the change in the flow rate of air at the inlet and outlet of the grinding chamber are presented in the table. To simulate a more realistic picture of the flow movement, the grinding bodies were added in a chaotic order, when grinding in the top chamber of a centrifugal grinding unit.

Table 1. Loss of speed (in%) with different parameters of pipes

		Confusor,°			
		20	30	45	90
Diffusor,°	20	7	14	13	49
	30	5	12	14	60
	45	9	15	18	31
	90	22	25	31	60

Software SolidWorksFlowSimulation allows you to theoretically get acquainted with the processes occurring in the grinding chamber in a static state, when blowing it with air flow. In addition, it is possible to determine the change in velocity along the entire length of the chamber, as well as the minimum loss of velocity and the establishment of rational values of the angles of the diffuser and confusor.

As a result of the calculations, the minimum loss of velocity in the chambers was determined at angles in the diffuser and confusor: $\alpha = 20$ °, 30 °, 45 ° and 90 °.

The loss of velocity is caused by multiple turbulence during the passage of the diffuser and resistance during the passage of the confusor. In fig. 3, 4, 5, 6, you can visually compare the results obtained in SolidWorksFlowSimulation.

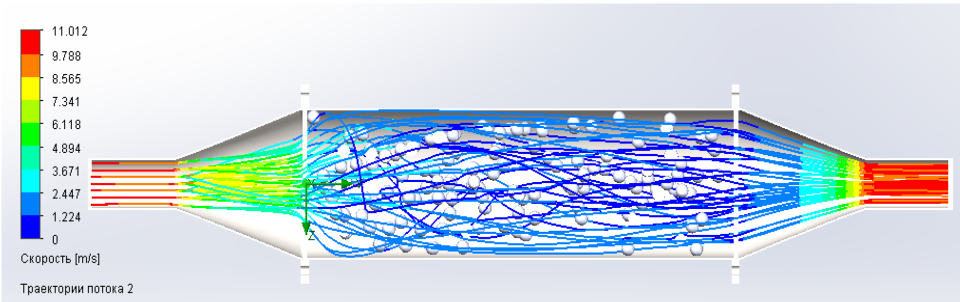

Figure 3. A visual representation of the flow paths at a diffuser and a confusor with angles of 20 ° (color gamut – change in velocity).

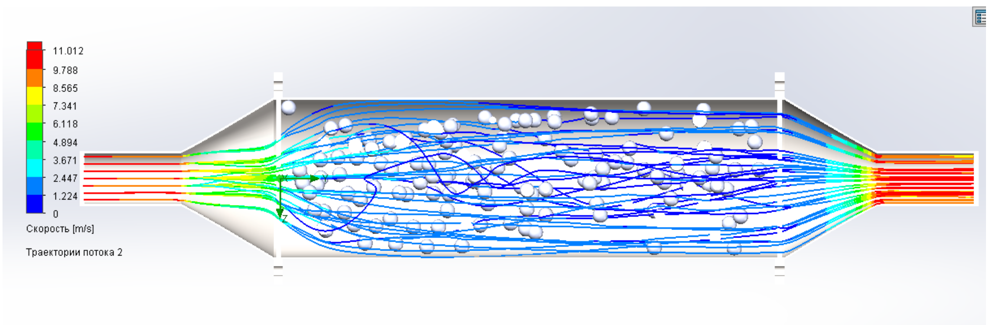

Figure 4. A visual representation of the flow paths at a diffuser and a confusor with angles of 30 ° (color gamut – change in velocity).

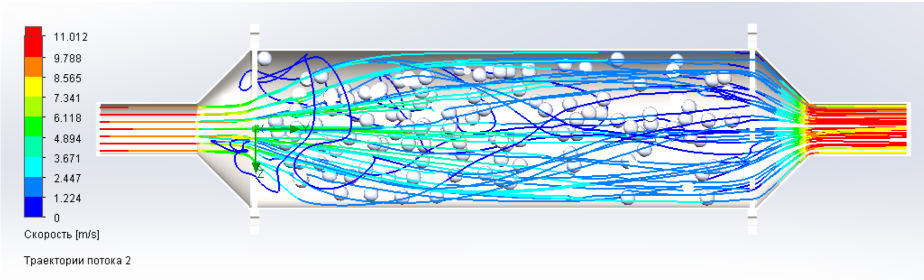

Figure 5. A visual representation of the flow paths at a diffuser and a confusor with angles of 45 ° (color gamut – change in velocity).

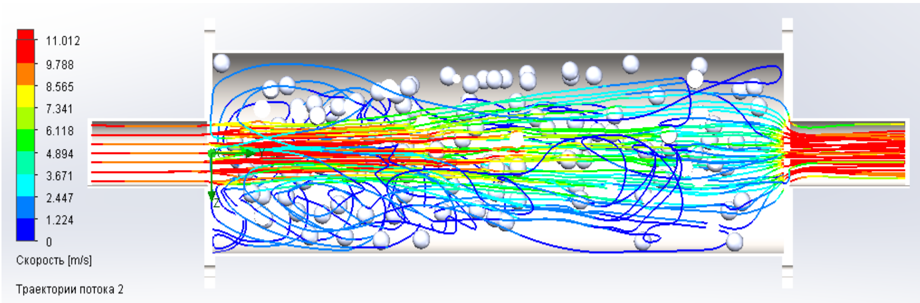

Figure 6. A visual representation of the flow paths at a diffuser and a confusor with angles of 90 ° (color gamut – change in velocity).

From figure 3 it can be seen how the gas (air) enters the grinding chamber through a diffuser of 20 ° taper, passes through a restrictive lattice, after which minor turbulences begin. It also passes through the grinding bodies, through the restrictive grid and smoothly passes through the confusor to the exit.

Fig. 6 shows that after passing the air through the cone of 90 through taper, there is a loss of speed and reverse flow and multiple turbulences appear.

In this case, turbulence plays a significant role in the classification of the material. With decreasing velocity, the flow captures the smallest particles. And when the flow is twisted, the large particles recline to the wall with the help of centrifugal forces and move on. This additional load on the crushed material allows one to increase the grinding efficiency.

4. Conclusion
The developed technological module, the design of which allows material particles with characteristics corresponding to the finished product to be removed from all the working chambers of the aggregate, prevents overgrinding and therefore ensures the required quality of the finished product and reduction of energy costs for grinding. Thereby that increases the grinding efficiency.

The carried out calculations make it possible to significantly simplify the determination of the design parameters of the grinding chambers, which provide the necessary mode of grinding the material in a centrifugal unit using a closed grinding circuit.

Acknowledgments
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References
[1] Bot G U 1966 Some problems of vibration grinding *Proceedings of the European Conference on Chopping* 435-443

[2] Lesin A D, Lokshina R V 1964 Designs of Foreign Vibrating Mills *Chemical and Oil Engineering* **4** 21-23
[3] Gridchin A M, Sevostyanov V S, Lesovik V S, Uralskii V I, Uralskii A V and Sinitsa E V, RU Patent No. 2381837 (11.03.08)
[4] Sevostyanov V S, Uralsky V I, Uralsky AV, Sinitsa E V 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **327** 042112
[5] Sevostyanov V S, Uralskij A V 2010 Multifunctional centrifugal aggregate with parallel grinding units *Bulletin of BSTU* **1** 106-112
[6] Kuzmina V P 2007 Mechanoactivation of materials for construction *Build. Mater.* **6** 74-75
[7] Pestsov V I, Bolshakov E L 1999 The current state and prospects for the development of the production of dry construction mixes in Russia *Building Mater.* **3** 3-5
[8] Borshchevsky A A and Ilyin A S 1987 Mechanical equipment for the production of building materials and products *Proc. for Univ. on Spec. "Construction of products and structures"* (Moscow: High school., 1987) 368 p.
[9] Uralsky V I, Sevostyanov V S, Sinitsa E V, Uralsky A V, Sazhneva E A, Farafonov A A, RU Patent No. 2651818 (24.04.2018)
[10] Bryukhanov O N, Korobko V I, Melik-Arakelyan A T 2005 *The Basics of Hydraulics, Heat Engineering and Aerodynamics* (Moscow: INFRA-M, 2005) 254 p.
[11] Idelchik E E, Steinberg M O 1992 *Handbook of Hydraulic Resistances* (Mechanical Engineering) **3** 672 p.