

Kinetics of process of product separation in closed system with recirculation

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Abstract. The object of an article is the extrapolation of the process of classifying material while passing in a model with the separation of the products of milling in the cleaning system includes a separator, concentrator, cyclone and a recycle loop. The model allows for the given parameters to predict the coarseness of grading of the finished product.

1. Introduction

The closed-loop milling system is a complex aggregate of the components and intersystem, which are linked by material and agromaterials flows. The most complex and poorly studied system is the separation of crushing products, which depends on both the quality of the final product and the efficiency of the overall process. The main task of modeling of the separation process is predicting the granulometric composition of the finished product. The finished product depends on the composition of the starting material, the constructive and technological parameters of machines and mechanisms involved in the separation process. However, at present apply only previously known system of separation of crushing products [1-3].

2. Materials and methods

When the product passes through the separating system, the predetermined granulometric composition of the finished product may not be provided. In this case, it is necessary to create a system of devices with recirculation. The proposed scheme for separating the products of grinding with recirculation is shown in Figure 1.



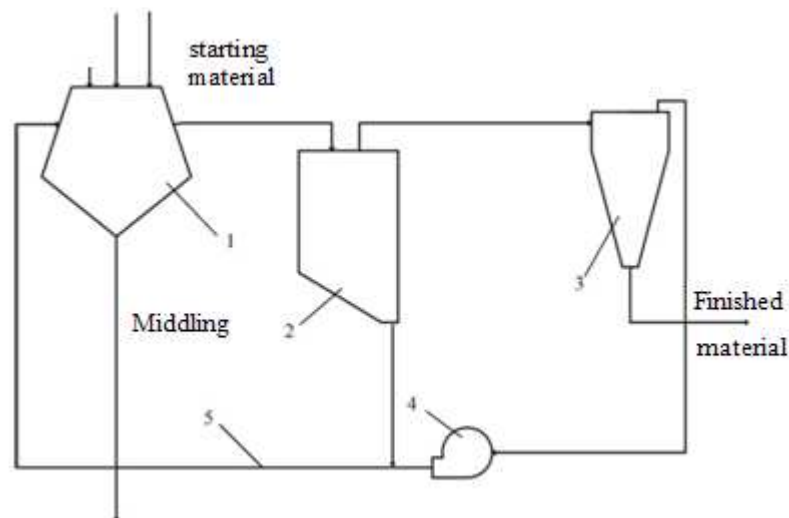


Figure 1. A scheme of separation of products of grinding with recirculation: 1-separator, 2-concentrator, 3-precipitation cyclone, 4-fan, 5 - recirculation flue

The material that enters separator 1 is a polydisperse medium. The separator separates the material. In this case, the separator is configured in such a way that a larger product than the finished material is extracted from it. Due to the smaller effect of orthokinetic coagulation, finer fraction will be carried out from the separator than with the traditional separation scheme [4]. Middling is returned to the mill, and the rest of the material enters concentrator 2, where gravity and inertial precipitation of large particles occurs. Due to greater inertia, large particles, depending on the concentrator setting, drop out of the flow into flue 5. Therefore, large particles, with a part of small concentrators, return to the separator from the concentrator. With the air flow, the small part corresponding to the finished product enters the cyclone. In the cyclone, dust is deposited in the finished product, which is removed. Purified air is supplied by means of fan 4 back to the separator via gas flue 5.

3. Mathematical calculations in a closed system with recirculation

Complete information about the separation process is provided by the separation curves. The determination of the parameters of the separation curve and the calculation of its characteristics from known design, technological or regime parameters of the system will in the future allow finding the granulometric composition of each separation product with the known initial composition of the material. The calculation is carried out according to [5].

Let the characteristics of the individual apparatuses entering the system be known. After each apparatus, it is possible to re-subdivide into a coarse and thin product. Therefore, the thin and coarse product separation curves are performed. The curve for the separation of the j -th apparatus on the output of the i -th product is ϕ_{ij} ($j = \overline{1, N}$, N - the number of apparatuses of the system, $i = 2$ - coarse, $i = 3$ - thin). Let us consider a simple closed loop, i.e. a circuit with the input of the original powder in one place with circulation of the material along a closed contour Figure 2.

The probability of carrying particles with a diameter to a thin product in the system of apparatuses is determined by the product of the probabilities of its release into a thin product in the first, second, and third apparatus.

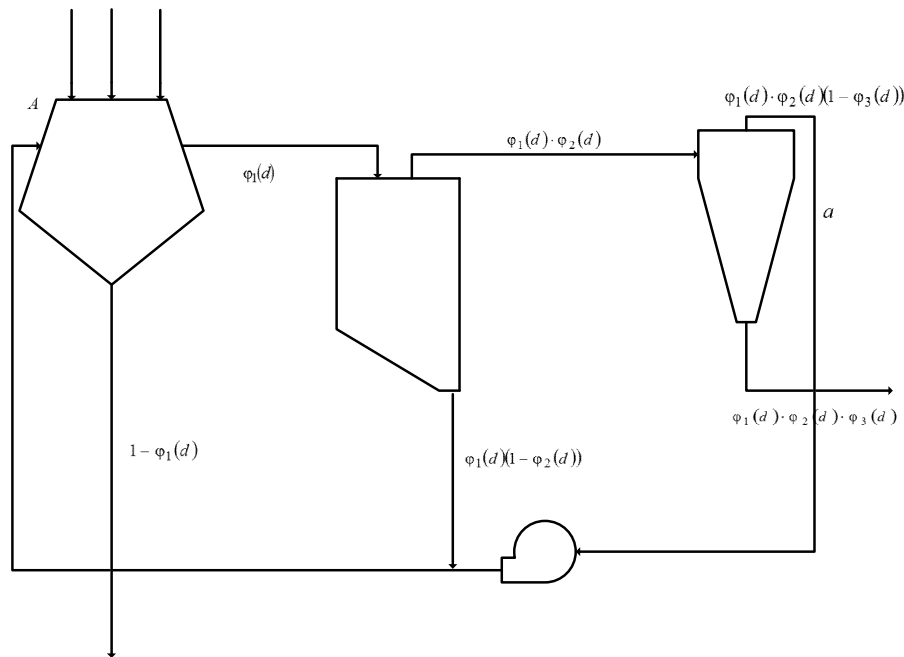


Figure 2. A scheme of the system of devices with recirculation of coarse product

Since the separation curves for the first $\varphi_1(d)$, second $\varphi_2(d)$, and third $\varphi_3(d)$ apparatus of the circuit are known, the separation curve of the relatively fine product separation will be determined by the expression:

$$\varphi_{33}(d) = \varphi_1(d) \cdot \varphi_2(d) \cdot \varphi_3(d) \cdot (1) \quad (1)$$

The probability of the particles falling into the coarse product of the first apparatus is:

$$\varphi_{21}(d) = 1 - \varphi_1(d) \quad (2)$$

The probability of the particles falling into the coarse product of the second and third apparatus is defined as the product of two and three successive events:

$$\varphi_{22}(d) = \varphi_1(d)(1 - \varphi_2(d)), \quad (3)$$

$$\varphi_{23}(d) = \varphi_1(d)\varphi_2(d)(1 - \varphi_3(d)). \quad (4)$$

For a closed system of apparatuses, the fractional removal is calculated as follows. Let at the initial moment the recycling share be zero ($a = 0$). If one takes the mass flow at the input to the device equal to unity, then the performance of the cascade for the coarse product $(B_2)_0$ is:

$$(B_2)_0 = 1 \cdot (\varphi_1(d) \cdot \varphi_2(d) \cdot (1 - \varphi_3(d)) + \varphi_1(d) \cdot (1 - \varphi_2(d))) \quad (5)$$

After the second and third apparatus, the material is recycled to point A. After n -th passing, letting n tend to infinity $n \rightarrow \infty$, one will get a fractional composition recycled to recirculation:

$$\lim_{n \rightarrow \infty} (B_2)_n = \frac{\varphi_1(d) \cdot \varphi_2(d) \cdot (1 - \varphi_3(d)) + \varphi_1(d) \cdot (1 - \varphi_2(d))}{1 - a \cdot (\varphi_1(d) \cdot \varphi_2(d) \cdot (1 - \varphi_3(d)) + \varphi_1(d) \cdot (1 - \varphi_2(d)))} \quad (6)$$

Fractional removal of a thin product taking into account the recirculation of the fraction of material is:

$$\varphi^P(d) = \frac{\varphi_1(d) \cdot \varphi_2(d) \cdot \varphi_3(d) \cdot (1 - a)}{1 - a \cdot \varphi_1(d) \cdot \varphi_2(d) \cdot \varphi_3(d)} \quad (7)$$

The separation curves of various apparatuses are described by the formula [6]:

$$\varphi(d) = \frac{1}{1 + \frac{d}{d_{zp}} \exp\left(-\frac{s}{2}\left(1 - \frac{d}{d_{zp}}\right)\right)}, \quad (8)$$

Parameter s is the analogue of the Peclet number [7] in diffusion processes. Despite limited prognostic abilities, this formula is used as a convenient approximating dependence. For the separator, the separation curve obtained in [8] has the form:

$$\varphi(d) = \exp\left(-\frac{0,00065 \cdot d^2 \exp(0,00021d^2)}{1 + 0,000053 \cdot d^2}\right). \quad (9)$$

Formula (9) takes into account the structural and technological features of the separator and is more accurate.

The curves for the separation of the concentrator ($Pe = 3,6$) and the cyclone ($Pe = 8$) for different values of d_{zp} are shown in Figure 3-4.

The probability of the particles falling into the coarse product of the first ($\varphi_{21}(d)$), second ($\varphi_{22}(d)$) and third ($\varphi_{23}(d)$) apparatus, as well as the separation curve of the relatively thin product division, calculated from (1) - (4), are shown in Figures 5-8.

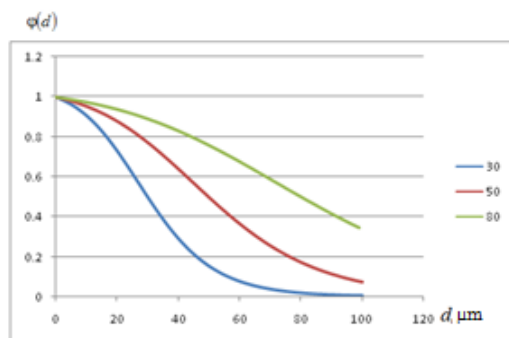


Figure 3. The curve of the concentrator separation for different values d_{zp}

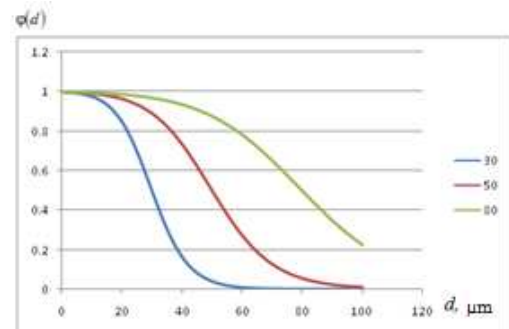


Figure 4. The cyclone separation curve for different values d_{zp}

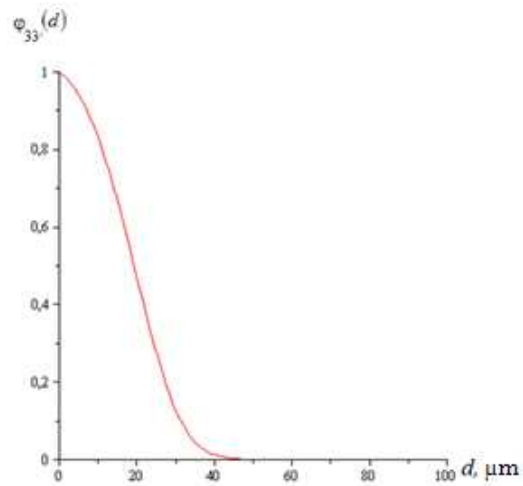


Figure 5. A separation curve of relatively thin product $\varphi_{33}(d)$

Figure 9 shows the fractional removal of a thin product, taking into account the recycling of the material fraction for the system: a) separator + concentrator + cyclone, and b) separator + cyclone.

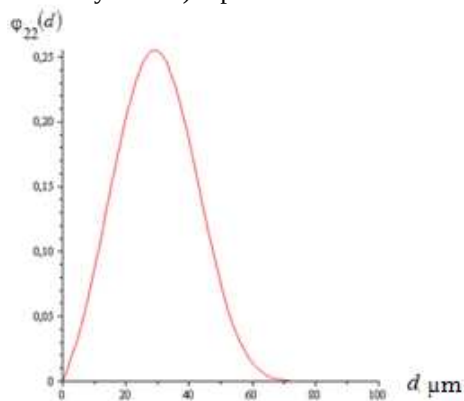


Figure 7. The probability of particles falling into the coarse product of the second apparatus $\varphi_{22}(d)$

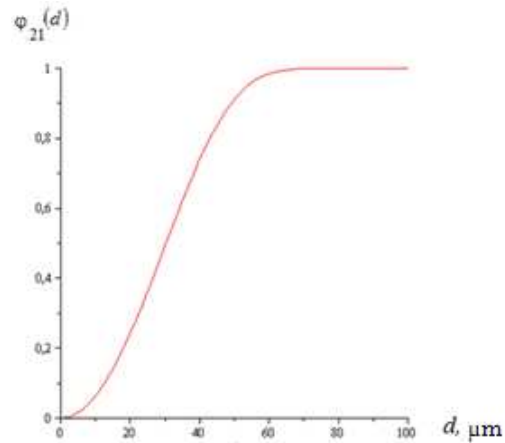


Figure 6. The probability of particles falling into the coarse product of the first apparatus $\varphi_{21}(d)$

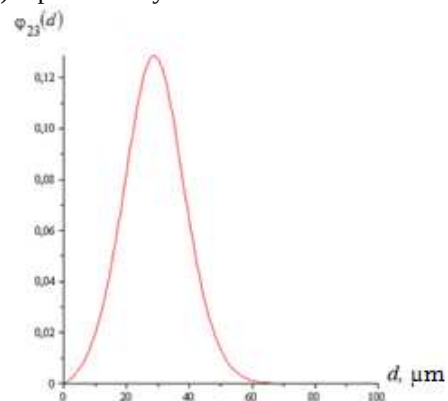
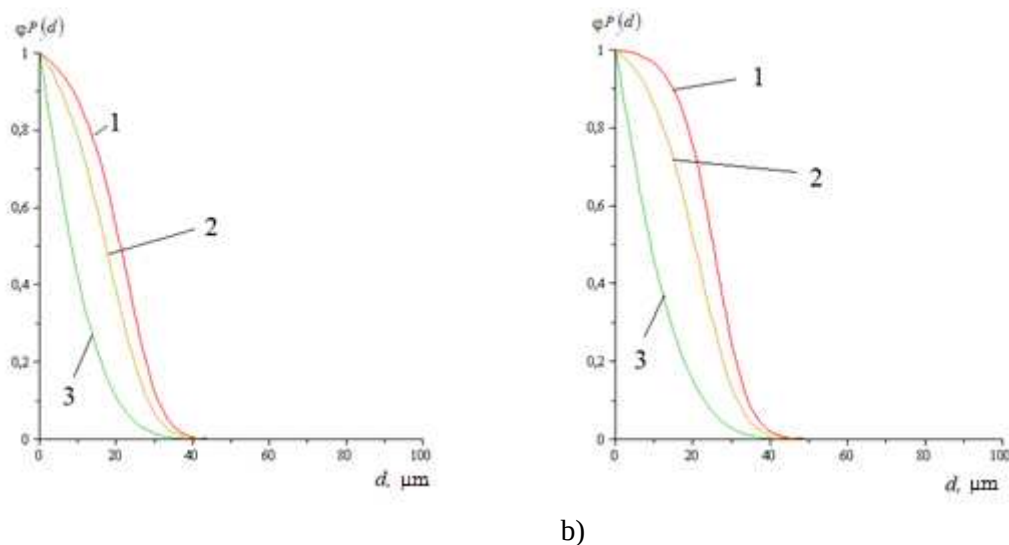


Figure 8. The probability of particles falling into the coarse product of the third apparatus $\varphi_{23}(d)$



a) b)
Figure 9. The fractional removal of a thin product, taking into account the recirculation of the proportion of the material is: curve 1 - $a = 0$; 2 - $a = 0.5$; 3 - $a = 0.9$. Thus, the curves for dividing the closed-loop system are calculated.

4. Conclusion

Based on the data from the separation curves, the classification process was predicted as the material passed through the proposed system of apparatuses with recirculation. Simulation showed that the efficiency of the proposed system is higher than that of the "separator + cyclone" system. So the maximum particle size passed by the system to the thin product for the proposed system "separator + concentrator + cyclone" decreased by 12% compared to the "separator + cyclone" system [9-11]. Also for the proposed system, the size of particles of the boundary size is $\varphi^P(d) = 0.5$.

Simulation showed that the proposed system of apparatus increases the efficiency of separating the products of grinding by reducing the orthokinetic effect. Adding the concentrator to the "separator + cyclone" system leads to a reduction in the maximum particle size of the finished product.

Acknowledgments

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References

- [1] Il'evich A P 1979 *Mashiny i oborudovanie dlya zavodov po proizvodstvu keramiki i ogneuporov* (Moscow: Vyssh. shkola)
- [2] Vetoshkin A G 2005 *Processy i apparaty pyleochistki* (Penza: state University)
- [3] Duda V 1981 *Cement* (Moscow: Stroiizdat)
- [4] Mizonov V E and Ushakov S G 1989 *Aerodynamic classification of powders* (Moscow: Chemistry)
- [5] Barskij M.D 1980 *Frakcionirovanie poroshkov* (Moscow: Nedra)
- [6] Trembovlya V I, Finger E D and Avdeeva, A A 1977 *Thermal performance testing of boiler plants* (Moscow: Energy)
- [7] Sharapov R R 2009 Scientific bases of creation and technological systems of cement grinding based on ball mill closed loop (Belgorod)
- [8] Uvarov V A, Klyuev S V, Orekhova T N, Klyuev A V, Sheremet E O and Durachenko A V 2014 The counterflow mixer for receiving the disperse reinforced composites *Research Journal of Applied Sciences* **12** 1211-1215

- [9] Orekhova T N 2011 Opredelenie proizvoditel'nosti pnevmosmesitelya suhikh stroitel'nyhsmesej s uchyotom analiza ustrojstv smesitel'nyh agregatov *Vestnik Belgorodskogo gosudarstvennogo tekhnologicheskogo universiteta im. V.G. SHuhova* **3** 65-68
- [10] Sharapov R R and Prokopenko V S, 2013 Modeling of the separation process in dynamic separators *World Applied Sciences Journal* **3** 536-542
- [11] Prokopenko V S, SHarapov R R and Agarkov AM, 2015 Optimizaciya raboty oborudovaniya dlya polucheniya tonkodispersnyh poroshkov *Vestnik Belgorodskogo gosudarstvennogo tekhnologicheskogo universiteta im. V.G. Shuhova* **1** 80-83