The decision of problem of reducing the temperature of cement during its grinding

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Abstract. The article is devoted to the question of improving the efficiency of grinding cement clinker. To improve the efficiency of grinding in ball mills closed circuit is proposed in the separation system to introduce fresh air. It is proposed to discharge excess separation air into a high-capacity filter. To solve this problem, the article makes a number of assumptions. For the calculation of the separation system, the expressions of the conversion of the initial product in the separator and flues of the system are given. The values of the concentration of the solid phase in different parts of the gas path of the separator are determined. On the basis of the obtained formulas, a system of equations is obtained, which allows to find the mass flow rate of fresh air. It is necessary to maintain the desired temperature of the separation process and the finished product. The dependence of the temperature of the finished cement on the volume of fresh air is obtained by the example of a closed circuit cement ball mill of the Belgorod cement plant.

1. Introduction

Portland cement is the main building material. It does not depend on the method of its production consumes a large amount of electricity [1-4]. Up to 40% of the consumed electric energy is spent on fine grinding of clinker and additives in ball and other mills [1, 5-8]. Ball mills that work with air separators [1, 9-14] are widely used to improve the efficiency of cement production and the quality of cement around the world. However, this grinding scheme does not solve the problem of the high temperature of the cement that leaves the grinding installation. Cement temperature can reaches 150 °C in summer time [1, 15-16]. To solve this problem, we propose to introduce fresh air into the air separator, which cools the hot cement. The resulting excess separation air is proposed to be discharged into the installed separation filter of higher capacity.

2. Theoretical

Due to the complexity of the processes accompanying the movement of gas streams in the separator gas ducts, let us take the following simplifying assumptions:
– gas-dispersed streams will be considered as streams of a continuous homogeneous medium, the density and viscosity of which depend on the concentration of solid particles;
– since pressure drops in gas ducts are significantly less than atmospheric pressure, we will take into account the dependence of air density only on temperature, kgm⁻³:
where \( p_a = 101325 \text{ (m}^3\text{kg}^{-2}\text{s}^{-2}) \) - normal atmospheric pressure; \( R = 287.14 \text{ (m}^2\text{s}^{-2}\text{K}^{-1}) \) is the specific gas constant of air; \( T = 273 + t \text{ }^\circ\text{C} \) - absolute air temperature, K;
– when estimating dustiness and viscosity of air streams, we will use average values of raw material and separation air flow rates;
– we will neglect the change in temperature of the gas streams during their movement in gas ducts and cyclones;
– due to the large cross-sections and the short length of the ducts, we will neglect the pressure loss due to friction;
– the dependence of the multiplicity of circulation and the effectiveness of cyclone precipitators on the flow rate and temperature of the separation air is not taken into account.you determine the expansion work done by stretching the area of cement clinker, you can calculate the value of the newly formed surface.

To predict the density of gas streams in different parts of the gas path, it is necessary to estimate the change in the concentration of the solid phase. In the separator, the source material \( G_m \) is divided into a thin product \( G_f \) and coarses \( G_c \), kg:

\[
G_m = G_f + G_c. 
\]

The main part of the thin product precipitates in cyclones and forms the finished product, kg:

\[
G_{cem} = G_f \eta_o, 
\]

where \( \eta_o \) is the total deposition coefficient (efficiency) of cyclones, %

The output of the finished product is associated with the receipt of the source material ratio, kg:

\[
G_{cem} = \frac{G_m}{k_c}, 
\]

where \( k_c \) is the multiplicity of the circulation of the material, %. From relations (3) and (4) it follows, kg:

\[
G_f = \frac{G_m}{\eta_o k_c}. 
\]

The part of the thin product that is not caught in the cyclones and enters the gas ducts:

\[
G_{du} = G_f (1-\eta_o). 
\]

Dividing the mass expenses of the source material and separation products by the average volumetric flow rate of the circulating air, we find the estimated values of the concentration of the solid phase in different parts of the gas path of the separator. Using the initial data given in [1, 10, 17], we obtain:

– at the entrance of the source material to the separation zone, kgm\(^{-3}\):

\[
Z_m = \frac{G_m}{Q}; 
\]

– at the exit from the separator and at the entrance to the cyclones, kgm\(^{-3}\):
the average concentration of the solid phase in the separator is equal, kgm\(^3\):

\[ Z_s = \frac{Z_m + Z_f}{2} = \frac{Z_m}{2} \left(1 + \frac{1}{\eta_kk_c}\right); \]  

(9)

– at the exit from cyclones and in the recirculation gas duct, kgm\(^3\):

\[ Z_{du} = \frac{G_{du}}{Q} = \frac{Z_m(1-\eta_k)}{\eta_kk_c}; \]  

(10)

– the average concentration of the solid phase in the cyclone, kgm\(^3\):

\[ Z_c = \frac{Z_f + Z_{du}}{2} = \frac{Z_m(2-\eta_k)}{2\eta_kk_c}. \]  

(11)

The greatest volume concentration of a solid phase, is reached on an entrance to a separator, is very small, m\(^3\)m\(^-3\):

\[ C_{v}^{\max} = \frac{Z_m}{\rho_m} = 0.0003, \]  

(12)

therefore, the density of gas streams in all parts of the gas path of the separator can be considered equal to the sum of air density and particle concentration, kgm\(^3\):

\[ \rho = \rho_\infty + Z \approx \frac{353}{T} + Z, \]  

(13)

and the viscosity of the gas mixture can be considered equal to the viscosity of air.

Next, consider the effect of the inflow of fresh air on the temperature of the separation process and the finished product. When mixed in the separation zone of separation air with the source material, due to its large specific surface, the interfacial heat exchange process proceeds very intensively, which leads to a quick (almost instantaneous) equalization of air and material temperatures.

In industrial conditions, when a separator is operating, there is always an unorganized supply of fresh air — suction through leaks and cracks.

The essence of the proposed modification of the separator is to create an organized and adjustable suction of fresh air into the gas path of the separator. Express the flow rate of fresh air in the form, m\(^3\)s\(^-1\):

\[ Q_f = K_fQ, \]  

(14)

where \(Q\) is the volume flow of separation air (including fresh air), m\(^3\)s\(^-1\); \(K_f\) is the relative volume fraction of fresh air, which varies from \(K_f = 0.05 \ldots 0.07\) — this is the suction during the usual recirculation mode of the separator, to \(K_f = 1\) with the direct-flow separator mode, which is installed with the rotary valve fully closed.

When mixing fresh and recirculated air, as well as in the process of material separation in the separator, the temperature of the separation air changes, so only its mass flow rate \(G_m\) is saved. The mass fraction of aspirated air \(K\) in the mass flow rate of separation air is expressed as follows, %:
\[ K = \frac{G_f}{G} = \frac{Q_f \rho_f}{Q_0} = K_f \frac{T}{T_{fr}}. \]  

(15)

Neglecting heat loss through the walls of the apparatus and ducts, we write the system of equations of material and heat balance in the form:

\[ G_f + G_r = G, \]  

(16)

\[ G_f C_r T_{fr} + G_r C_r T + G_m C_m T_m = G_m T_{cm} + GC_T, \]  

(17)

where \( G_f, G_r, G \) are the mass flow of fresh supply, recirculation and separation air, kgs\(^{-1}\); \( T_{fr}, T_m, T \) are the absolute temperatures of the supply air, the source material and the finished product, K; \( C_r = 1005 (m^3 s^{-2} K^{-1}) \); \( C_m = 800 (m^3 s^{-2} K^{-1}) \) is the specific heat capacity of air and material (cement).

The solution of the system of equations (16, 17) can be written in two forms:

\[ G_f = \frac{G_m C_m (T_m - T)}{C_r (T - T_{fr})}, \]  

(18)

\[ T = \frac{C_f C_r T_{fr} + G_m C_m T_m}{G_m C_m + C_f C_r}, \]  

(19)

Expression (18) allows us to find the mass flow rate of fresh air that is needed to maintain the desired temperature of the separation process and the finished product, and the ratio (19) allows us to investigate the dependence of this temperature on the flow rate of fresh air. Graph of \( t = T - 273 \degree C \) versus \( Q_f = G_f T_{fr}/353 \) for the summer period and separator parameter values \( t_{fr} = 25 \degree C, Q = 22.2 m^3 s^{-1}, G_m = 33.3 kgs^{-1}, t_m = 130 \degree C \) is shown in the figure 1.

![Figure 1](image1.png)

**Figure 1.** The dependence of the temperature of the finished product on the volume of fresh air.

### 3. Conclusion

From the figure 1 it follows that at \( Q_f = 0.83 m^3 s^{-1} \) (the usual recirculation mode of the separator with suction) the temperature of the separation air and the finished product is \( t = 127 \degree C \), and in the direct-flow mode (\( Q_f = 16.7 m^3 s^{-1} \) ) \( t = 88 \degree C \).
The optimum temperature mode of operation of the separator \( t = 90 \ldots 105 \, ^\circ C \) is achieved with a relative share of fresh air \( K = 0.35 \ldots 0.70 \), i.e. 35 \ldots 70%.

Reducing the temperature of cement can improve not only the quality of cement, but also the performance of the mill. This is because the separator in addition to the finished product is cooled and coarses. When you return to the mill cooled coarses cools the very grist mill. The grinding process is more efficient.

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