Investigating and comparing the effect of process optimization and use of a grinding aid on improving the performance of cement mill department in a cement plant

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(Manuscript Submitted November 25, 2018; Accepted March 10, 2019)

Abstract
Producing cement with appropriate quality and by spending the minimum cost, applying solutions including process optimization and use of grinding aid have been investigated before. This paper compares and investigates the effect of process optimization and use of grinding aid on the operational capacity and blaine of final product in two cement mill departments in a cement plant. The results of a specific grinding aid test and its effect on the quantity and quality of the final product were compared with the results obtained from process optimization of cement mill lines 1 and 2 of a cement plant including optimization of the arrangement and tonnage of the charge of balls. The results suggested that the operational capacity of cement mill of lines 1 and 2 when optimizing the process conditions increased by around 9.4 and 15%, and the blaine of the final product of the department rose by about 4.6 and 4.3% respectively compared to the case of using the grinding aid. It should be noted that performing the grinding aid test only resulted in enhanced operational capacity of cement mills, and had no significant effect on the parameter of quality (blaine). On the other hand, performing the process optimization had positive effects on both quantity and quality.

Keywords: Cement mill, Process optimization, Grinding aid, Operational capacity, Blaine, Specific electric energy consumption.

1. INTRODUCTION
Use of grinding aids can have positive effects on the quantitative and qualitative conditions of cement mill, and so far, different studies have been performed in this regard. Low operational capacity and the final product blaine are among the common problems in crushing and grinding departments. One reason can be jamming and agglomeration of softened particles on balls [1, 2]. Evaluating the process potentials available for improving the mill performance is considered crucial, and therefore, due to the need to produce high-quality cement with minimum costs, application of solutions including process optimization and use of grinding aids is suggested in the case of grinding and crushing [3, 4]. Use of grinding aids results in decreased retention time of materials in the mill as well as energy consumption. Nevertheless, for general assessment, technical and economic considerations should also be taken into account. In this regard, first, technical assessment is performed (including measuring process parameters and use of grinding aids), then economic assessment is done, although it is not easy to measure [5, 6].

During the last decade, semi-finish-grinding plants have been used more and more for the energy efficient grinding of high-quality cement. Recent research has shown that the operational performance of the ball mill, which is situated downstream of the high-pressure grinding roll separator cycle, can be improved significantly by using grinding aids [7, 8]. The different approaches for increasing the energy efficiency of dry fine grinding processes can roughly be divided into three groups: (a) further development of mills and mill equipment, (b) improving classifiers as well as grinding-classifying-circuits and (c) enhancing the process behavior of the ground material [9, 10]. The cement grinding operation is performed in dry environment hence the agglomeration tendency of the fine powders is the major problem, which could be overcome by the introduction of the grinding aids. Most of the grinding aids consist of organic compounds. Amines, glycols, and phenols have been used as raw materials which constitute the main ingredient of grinding aids [11, 12].

In this paper, first the method and procedure are presented based on the proposed solutions including measuring the process parameters and the use of grinding aids. Next, the results obtained from process optimization and use of grinding aids on operational capacity and the final product blaine are compared and investigated in two cement mill departments lines in a cement plant. The innovation of this study is applying the mass and energy balance equations for all the equipment and solving the system of equations numerically in order to obtain the unknown values. The

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flow diagram of the cement mill department lines 1 and 2 is shown in Figs. 1 and 2.

Fig. 1. The flow diagram of the cement mill department of line 1 in the studied cement plant (The dotted lines represent the path of gas flow, while the bold lines show the path of solid flow)

Fig. 2. The flow diagram of the cement mill department of line 2 in the studied cement plant

2. METHODS

In this section, a summary of the stages of performing each of the proposed solutions including process optimization (A) and use of grinding aids (B) in the cement mill department is presented.

A) Process optimization in the cement mill department and enhancing the product both quantitatively and qualitatively involves the following stages:

I. Measuring the process parameters in the department, performing engineering computations, and determining the values of indices to identify the hidden possible potentials in the system.
II. Taking samples from different flows around the separator in order to determine the separation efficiency of the separator and investigating the distribution of particles inside the separator.

III. Internal inspection of different equipment of the department to investigate the corrections and changes required in the department.

IV. Taking samples from the flow of materials and the balls inside the mill chambers to investigate the distribution of particles along the mill and determine the grinding profile.

V. Determining the tonnage of ball charges, arrangement of balls (percentage of each ball size), as well as corrective measures required in the equipment of the department.

B) The stages of performing the grinding aid test in the cement mill department lines 1 and 2 include:

I. Injecting grinding aid with dosages of 520 and 750 ml/min in the input feed of the cement mills lines 1 and 2 respectively (given the capacity of the mill).

II. Monitoring the process conditions and system performance and recording stable tonnages of 85 and 100 ton/h for cement mills lines 1 and 2 after performing the grinding aids test.

2.1. GOVERNING EQUATIONS AND OPTIMIZATION METHOD

After measuring the process parameters (temperature, static pressure of gas flow, and gas flow rate) in each of the ducts of the gas flow in the department, mass and energy balance equations around each of the process equipment (ball mill, separator, fans, and filters) are written as Eqs. 1 and 2 [13]:

\[ \rho V_i + \rho V_f = \rho V_c \]  
\[ \rho V C_p T_i + \rho V C_p T_f + E_i = \rho V C_p T_c + HL \]

In these equations, \( \rho \), \( V \), \( C_p \), and \( T \) represent the normal density, normal volume of gas flow, specific heat capacity, and temperature of the flow, respectively. Normal density and normal volume of gas flow are defined at normal conditions (1 atm and 0°C). Further, the subscripts i, f, and o show the input flow of each equipment, the input leaked airflow to the equipment, and the output flow leaving the equipment. \( E_i \) shows the input energy value to the system (the input energy of the main engine for the mill and fans), and \( HL \) represents the extent of heat loss off the equipment body.

These mass and energy balance equations were individually written for all the equipment. Also, the resulting systems of equations were solved using the Gaussian elimination method in order to obtain the unknown values (the amount of leaked input air and output gas leaving each equipment). After specifying all the values of the process parameters, optimization of values was performed using the gradient descent method in order to achieve the best values of process indices for proper functioning of the process [14].

3. RESULTS AND DISCUSSION

In this section, the results of a specific grinding aid test and its effects on quantity and quality of the final product are compared with the results obtained from process optimization of cement mill lines 1 and 2 of a cement plant. The optimal arrangement and tonnage of charge of balls are presented based on the results of process measurements in the cement mill departments, internal inspection of the relevant equipment, and taking samples from the materials and balls inside the cement mill chambers.

| Table 1. Quantitative and qualitative parameters in the cement mill department lines 1 and 2 of the cement plant obtained from process optimization and grinding aid test |
|-------------------|---------------|-------------------|
| Parameter         | Cement mill no. | Grinding aid test | Process optimization |
| Operational capacity of cement mill (t/h) | Line 1 | 85 | 93 |
| Blaine of final product (cm^2/g) | Line 1 | 3250 | 3400 |
| Line 2 | 3450 | 3600 |

In Table 1, the values of operational capacity and blaine of final product in the cement mill department lines 1 and 2 are compared in the two conditions of process optimization and grinding aid test. The results reveal that the operational capacities of the cement mill lines 1 and 2 in the case of optimization of process conditions were greater than those of the grinding aids test by around 9.4 and 15%, respectively. Further, in the process optimization state, the final product blaine of the cement mill department lines 1 and 2 increased by around 4.6 and 4.3%, respectively compared to the grinding aid test, which is one of the influential factors for improving the qualitative properties of the final product (strength, cement setting time and density.).

Figures 3 and 4 display the operational capacity and final product blaine values as compared across three conditions:

- initial conditions (before optimization and grinding aid test)
- after performing the grinding aid test
- after performing process optimization

Further, Fig. 5 compares the specific electric energy consumption of the main engine of the cement mills for the conditions after process optimization with initial conditions.

As can be seen in Fig. 3, performing the process optimization has resulted in achieving the maximum operational capacity in both lines of the cement mill when compared to the grinding aids test. Further, the operational capacity value after performing process optimization for the cement mill lines 1 and 2 rose by 31 and 22.3% from the initial conditions, respectively.

As can be observed in Fig. 4, performing the grinding aid test did not significantly affect the final product blaine (quality), as compared to the initial conditions of the mill. However, performing the process optimization caused enhanced blaine for the cement mill of lines 1 and 2 by 7.9 and 5.9%, respectively compared to initial conditions. Therefore, by comparing Figs. 3 and 4, it can be concluded that performing the grinding aids test only caused enhanced operational capacity of cement mills, but had no effect on the quality (blaine). On the other
hand, performing the process optimization had positive effects on both quantity and quality parameters. Figure 5 demonstrates that performing the process optimization resulted in reduction of specific electric energy consumption of the main motor of cement mill lines 1 and 2 by 14.7 and 16.7%, respectively, compared to initial conditions. Therefore, it can be concluded that performing the process optimization resulted in diminished specific electric energy consumption of the main engine, resulting in the decrease of the electric energy costs of the department.

4. CONCLUSIONS

In the present study, the results obtained from a specific grinding aid test were compared with the results obtained from process optimization of cement mill process lines 1 and 2 of cement plant and its impact on the quantity and quality of the final product. The results indicated that the operational capacity of the cement mill lines 1 and 2 when performing process optimization increased by around 9.4 and 15% and the final product blaine of the department rose by about 4.6 and 4.3%, respectively compared to the grinding aid test. Further, performing the process optimization resulted in reduction of specific electric energy consumption of the main motor of cement mill lines 1 and 2 by 14.7 and 16.7%, respectively, compared to initial conditions. It can be concluded that performing the grinding aid test only resulted in enhanced operational capacity of the cement mills compared to initial conditions, and had no effect on the parameter of quality (blaine). On the other hand, performing the process optimization offered positive effects on both quantity and quality. Therefore, it can be stated that process optimization in the department offers more advantages and positive effects both quantitatively and qualitatively as well as in terms of the costs when compared to merely using grinding aid.

REFERENCES


