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The influences and selection of grinding chemicals in cement grinding circuits

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HIGHLIGHTS

- Industrial sampling campaigns were arranged for different grinding chemicals.
- Performances of each chemical were evaluated.
- The influences on milling and classification units were discussed.
- Economic evaluations were performed.
- A methodology on selecting the most feasible chemical was developed.

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ABSTRACT

Within the study, the results of the test works performed around a cement grinding circuit in order to select the most appropriate option are presented. In this context, sampling campaigns were arranged with different grinding aids and mixed products then the influences were discussed by considering the changes in production rate, equipment performance, energy consumption, cement quality and clinker saving parameters. The results implied that the production rate of the circuit and the 28-day strength of the cement could be increased by 24% and 3.5% respectively with the selection of an appropriate chemical. In addition, the use of chemicals may reduce the clinker consumption by 5% that is important regarding to CO_2 emissions. The studies concluded that triethanolamine based chemical had better performance parameters than the other types.

1. Introduction

Cement is an important material that its consumption has been steadily increasing depending on the construction business growing all around the globe [1]. However, the manufacturing process is known as energy intense since the energy utilization is about 110–150 kW h per tonne of cement varying with the process modernization and raw materials used [2]. Broadly, the process is composed of many sub operations including raw meal preparation and grinding, pyrometallurgical process, finish grinding. In these stages comminution activities account for about 30% of the total energy consumption, therefore attention should be drawn to optimize the circuits.

Energy efficiency of a grinding circuit, whether it is wet or dry, is affected by operating and design parameters including, mill diameter, mill length, media size and filling, throughput, classifier design etc. In addition to these variables, material characteristics also have influence on the entire operation. In wet grinding applications the material properties can be expressed in terms of slurry rheology that affects the performances of milling and classifying machines. Dry grinding is a challenging process regarding to the material transportation where the particles are prone to form agglomerates and coat on media as well as the mill liners owing to the static forces arising during grinding action. Mill ventilation improve the milling performance up to a certain extent but it is not sufficient to prevent the coatings.

Rehbinder and Kalinkovaskaya [3] introduced chemicals that reduced the solid surface energy while the new surfaces were generated following the grinding action. Klimpel and Manfroy [4] also approached the function of the chemicals in the same manner. They reported that, the surface of the particles are neutralized hence the probability of forming agglomerates and coatings is reduced that ultimately provides more efficient grinding environment. In addition, the bulk material becomes fluidized and that makes the transportation along the mill easier. Today, grinding chemicals are reported as capacity improvers or in some cases strength enhancers. Cement grinding operations demand these chemicals in order to improve its energy efficiency. As it is a dry

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grinding environment, more benefits are observed compared to wet grinding applications.

Regarding to the explanations on particle-chemical interaction, so many studies have been reported in the literature. As mentioned previously, Rehbinder and Kalinkovaskaya [3] proposed that energy to produce a given amount of surface could be reduced by decreased solid surface energy that was believed intuitively to be responsible for the improved efficiency. They indicated that the particle became easy to break when it absorbed a chemical into its structure. However, Westwood and Goldheim [5] discussed the results came up from Rehbinder and Kalinkovaskaya [3] and reported that the use of chemicals do not change breakage characteristics of the particles. Then summarized that such a behaviour could be possible only when plastic deformation is dominant in fracture thus cannot be used in explaining the interactions in tumbling mills where the impact fracture prevails.

As reported earlier, the grinding chemicals have two applications, which are; the modification of the surface charge of particles and the improvement of the ultimate cement strength. For these applications, varieties of products have been manufactured by number of producers. Some of the products are pure grinding aids, some them are strength enhancers and the rest are called as mixed (grinding aid–strength enhancer) products. Certainly, the differences in their compositions will have different responses from the process regarding to the energy efficiency and cement properties. The objective of the study is to reveal these differences by means of conducting the industrial scale test studies around a cement grinding circuit for a given cement type. In this context, 3 different grinding aids and 3 different mixed products were tested at their predetermined dosages defined by the manufacturers. The grinding chemicals were in the liquid form and fed from the fresh feed conveyor. The results of the studies were evaluated by taking economy, cement quality and energy efficiency parameters into consideration. As a result of the studies, performances of pure grinding aids and the mixed products were compared and the most suited chemical was selected for a given cement type.

2. Materials and methods

2.1. Experimental studies

Within the scope of the study, 6 commercial grinding chemicals having different active ingredients were tested that are specified in Table 1.

The experimental studies cover the material characterization works. In terms of characterization, the particle size distribution and surface area of the streams, 28-day strength of final product were measured. The size distributions of the samples were determined by combining two different measurement techniques. Initially, dry sieving technique was applied to the materials from top size to 150 μm, after that the measurement was completed via laser scattering method that enabled to determine the distribution down to 0.5 μm. The size distributions obtained from each test were both used to evaluate the size reduction performance of the mill (F_{50}/P_{50}) and classifier performance by drawing and discussing the influences on the Tromp curve [6]. An example of particle size measurement around the grinding circuit while using one of the chemicals is illustrated in Fig. 1. The similar trends were obtained for the other chemicals as well.

The surface area of the bulk material can be represented by Blaine number. Blaine is an air permeability method that determines the time taken for a fixed quantity of air, flowing through a cement bed of specified dimension [7]. Atom Teknik device was used to carry out the measurements for the final product samples.

Table 1
Grinding chemicals used.

Chemical	Active ingredients
A	Organic, inorganic and aqueous solution of modified amines
B	Alkanolamines and alkanolamine salts
C	Aqueous solutions of amine acetate salts
D	Hydroxylamine based
E	Blend of polycarboxylate and amines
F	Triethanolamine based

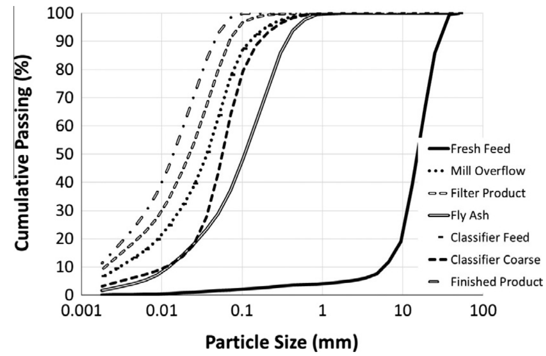

Fig. 1. Obtained particle size distributions from one of the surveys.

The surface area measurements together with cement quality were determined at Cimentas Izmir Cement Plant by applying the standard procedures defined in TS EN 196-1.

2.2. Sampling campaigns

For performance evaluation of a circuit, sampling campaign is the beginning of all the studies that enables to follow up the changes in size distributions and product quality, hence the equipment performances throughout the process. For this reason, it should be carried out rigorously. Within the study 3 grinding aids and 3 mixed products (grinding aid-strength enhancer) were tested around a cement grinding circuit at the same cement type (CEM II A-M (LW) 42.5 R). In this type of cement the raw meal includes clinker, limestone, fly ash and gypsum. Throughout the sampling studies, raw meal compositions were constant as the chemical assays were undertaken periodically hence a stable feeding was provided. The simplified flow sheet of the circuit together with the sampling points is illustrated in Fig. 2. As can be seen from the figure, only the fly ash is fed from separator feed stream owing to its fine size distribution.

The existing grinding circuit is composed of two compartment ball mill that is closed circuited with 3rd generation dynamic air classifier. The mill filter at the discharge of the mill is employed for ventilating purpose and help material transportation particularly in the second compartment. At the same time it collects fine particles from inside however it is not fine enough to be sent directly to cement product silos hence it is subjected to the classifier feed stream which will be discussed later. Target product size from the circuit is obtained by adjusting the operating conditions of dynamic air classifier where the fines stream are reported to the silos and coarse particles are circulated back to the mill repeatedly. The technical specifications of the equipment in the circuit are given in Table 2.

The ball mill in the circuit has 2 grinding compartments. In the first one, lifting liners are preferred to lift the grinding media high enough in the mill to ensure that an impact action takes place between the media and the material being ground. Second chamber linings are designed firstly to enable an attrition grinding action and secondly to produce an automatic segregation of the grinding media named as classifying liner. The view of the liners are illustrated in Fig. 3. The ball size distribution and media charge level of the first and second compartments are given in Table 3.

The sampling campaigns around the circuit were performed when steady state conditions were established. For this purpose, the parameters such as the power draws of the machines e.g., ball mill, ball mill elevator as well as the flow rates of the streams e.g., fresh feed, separator reject, recorded in the control room were all followed. An observed graph during sampling studies is illustrated in Fig. 4. Mill power parameter can be read from secondary *y*-axis and the rest are from the primary one.

Tables 4 and 5 give the control room parameters recorded during sampling studies of grinding aids and mixed products. As can be followed from the tables, all of the samples were collected at the same target size and surface area values therefore the product size distribution curves are similar to each other (Fig. 5). Moreover, the clinker ratio of the cement while using the mixed product (grinding aid + strength enhancer) was decreased to 75% to observe whether the same cement quality could be obtained with reduced amount of clinker.

3. Results and discussion

3.1. The influences on circuit performance

In order to evaluate the performance of a grinding circuit, all of the flow rates around the circuit should be calculated and the size distributions measured should be corrected as it may contain