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The effects of grinding aids on modelling of air classification of cement

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HIGHLIGHTS

- This study investigated the effects of grinding aids on air classification performance.
- Dosage rate and the type of grinding aids had effects on air classification performance.
- Grinding aid based classification model was developed.

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ABSTRACT

Until so far, several studies have been performed on grinding aids which have discussed the influences. However, the evaluations were all based on closed circuited grinding operations where the milling and the classification operations were integrated and had effect with each other. The novelty of this paper comes from its comprehensive test works with only on air classifier and development of grinding aid-specific model structure that has not been performed. Within the scope, laboratory scale air classifier was utilized and triethanolamine (TEA), triisopropanolamine (TIPA), and diethylenglycol (DEG) were mixed with cement at various dosage rates. The experimental tests were performed at different wheel speed and air flow rates then the performance of the air classification was evaluated by plotting the Tromp curves. As a result, the limited change was observed for cut size and sharpness parameters however, bypass and fish hook parameters changed significantly. Among the grinding aids tested, TIPA type aid was found to be more effective on both bypass and fish hook parameters. Finally, the air classifier was modelled by using Whiten's equation and the relations between dosage rate, type and model parameters were investigated. The results concluded that different types of grinding aids had varied influences and the model structures needed to be developed accordingly.

1. Introduction

Cement is a highly-consumed construction material and has an energy intense process where the total specific energy consumption is reported as between 110 and 120 kW h per ton of product. Within the whole process grinding operation accounts for about 30% of the total energy consumption [1] in which the ball mills and air classifiers are employed conventionally. Within the process, the aim is to achieve the desired product specifications i.e., specific surface area, mean particle size etc., which are all have effects on the strength values. 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 [2]. Up to now, ethylene glycol, propylene glycol, triethanolamine, oleic acid, and aminoacetates have been used as raw materials of the grinding aids found in the cement grinding applications [3].

The mechanisms of the grinding aids have been explained by several of the researchers. Rehbinder and Kalinkovskaya [4] pointed out that the adsorption of the additives reduced the cohesive forces hence bonding of the molecules improved. Klimpel and Manfroy [5] concluded that adsorption of the grinding aids affected the magnitude of the bonding forces at the point where fracture initiates. Westwood and Stoloff [6] suggested that the adsorbed molecules could pin dislocations near the surface that was thus rendered more brittle. Locher and Seebach [7] stated that the use of chemical additives did not affect the breakage characteristics of the particles, however they pointed out that Van der Waal's forces between the particles decreased that enabled more efficient breakage action. Additionally, as a result of the reduced Van der Waals forces the bulk material became more fluidized that directly affected the retention time in the grinding operations [8]. Weibel and Mishra [9] conducted experimental studies as well as com-

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puter simulations to reveal the physical and chemical mechanisms of the grinding aids used in the cement operations. They stated that molecular and material properties had effects on grinding with grinding aids and emphasized the importance of understanding the effects and interactions between them. They concluded that it was possible to optimize the grinding performance and other properties such as flowability, early/late strength development and the workability of cement mortar and concrete.

When a conventional cement grinding circuit is considered, two units come forward that are the ball mills and the air classifiers. In ball milling, numerous researches have been undertaken to investigate the influences of the grinding aids. Sverak et al. [10] studied on different types of grinding aids and discussed the effects on the milling operations. They concluded that each type of the grinding aid had varied effects on the grinding results. Sohoni et al. [11] discussed the results of batch grinding tests where different types of grinding aids were used in grinding of cement clinker, limestone and quartz. They observed that the use of grinding aid reduced coatings on the mill shell, in particular when grinding of limestone and clinker, and provided a steady operation since the agglomeration tendency was reduced. Similarly, Oksuzoglu and Ucurum [12] performed batch grinding tests for various types of grinding aids and at different dosage rates. They proved that the use of grinding aids improved the grinding performance of the mill. Gokcen et al. [13], Altun et al. [14] studied the effects of grinding aids on the performance of the stirred media mills. They stated that the use of grinding aids improved the grinding results meaning that the specific energy consumption of the grinding operation reduced. Basically, the improvements in the milling performances was attributed to the reduced amount of coatings while Bond work index of the material was said to be constant [15]. Assaad [16] studied on glycol based grinding aid at 2 different dosage rates to relate the grinding results of laboratory and real scale cement milling operation. It was concluded that specific energy consumption decreased with the introduction of grinding aids. In addition to the specific energy consumption, cement properties were also investigated. It was found out that cement properties had altered due to the change in the shape of the size distribution curve. Assaad [17] investigated how the performance of the grinding aid used in cement grinding varied with the temperature. It was concluded that increase in the level of temperature altered the performance of the additive used since the strength of cement decreased significantly.

In contrast to the grinding operation, in the literature, the studies investigating the impacts on the air classification are limited hence this study aims to fulfil the needs in that field. The novelties of this paper come from its extended test works with different types of grinding aids by utilizing laboratory scale air classifier. Briefly, the influences of different types of grinding aids were revealed and grinding aid-specific model structures were developed hence the predicting capabilities of the simulations could be improved that have not been performed so far. The novelties can be summarized as;

- The influences of different types of grinding aids on cement classification were discussed independent of the grinding operation.
- The effects of dosage rate fed directly from the separator feed were able to be discussed.
- The grinding aid-specific model structure for the classifier was developed.
- The developed model structures are to be utilized in the simulation software and the predictions can be more accurate.

Within the scope, 3 types of aids named as, DEG (diethylene glycol), TEA (triethanolamine), TIPA (triisopropanolamine) were utilized and different operating conditions i.e., varied rotor speed, dosage rate and air flow rate, were adjusted. Then the performance of the classifier was evaluated by plotting the efficiency curves. Afterwards, the model structure of the air classifier was developed and the parameters of each type of aid were calculated to discuss the differences between them. It should be emphasized that the developed model structure is valid for the cement and air classifier specified in the following sections.

Such a study is thought to be beneficial for both cement and chemical manufacturers to understand what kind of differences are observed depending on the type of the grinding aid. In the end, by choosing proper type of grinding aid, the processes can be optimized in terms of specific energy consumption and the cost per ton of cement.

2. Materials and methods

2.1. Description of the experimental apparatus

The experimental tests were undertaken with Alpine 100 MZR Classifier (Fig. 1). The operational range of the classifier is reported as between 2 and 80 μm and feed rate is between 2 and 6 kg based on the density of the material. During the operation, target size of the product is adjusted by changing the wheel speed and the air flow rate, which range between 1000 and 15,000 rpm, 5 and 50 m^3/h respectively.

Fig. 2 illustrates the cross-sectional views of the classification chamber, rotor structure and the influencing forces in the classification. The classifier has a rotor/wheel structure with zigzag shape and there exist channels that radially arranged (Fig. 2b).

During the classification, the particles entering the classification zone are under the influence of drag, centrifugal and gravity forces thus either subject to the coarse or the fine stream (Fig. 2c). The drag force is imparted by air, which flows through the outside of the rotor to the inside and leaves the chamber by taking the fine particles with it. Coarse material that is flung by the centrifugal

Fig. 1. Alpine 100 MZR air classifier.