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Utilization of grinding aids in dry horizontal stirred milling

Okay Altun [a,*], Hakan Benzer [a], Alper Toprak [a], Udo Enderle [b]

[a] Hacettepe University, Mining Engineering Department, 06800 Beytepe, Ankara, Turkey
[b] Netzsch Feinmahltechnik, Sedanstraße 70, 95100 Selb, Germany

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ABSTRACT

Within the context of the study 3 types of grinding aids, which were glycol-based, TEA-based and TIPA-based, were tested in dry stirred milling of cement. The objective was to evaluate their influences on mill performance and cement quality then find out the most proper type with its dosage rate. The results showed that use of grinding aid improved the grinding performance of the mill as finer size distribution than that of no grinding aid was obtained at the same milling condition. The tests at the same dosage rate indicated that, TIPA-based grinding aid had the lowest specific energy utilization with 16.8 kWh/t compared to that of glycol (17.9 kWh/t) and TEA-based aids (19.75 kWh/t) respectively. The product size distributions showed that TIPA-based aid had finer product with d_{50} of 10.54 μm compared to other types. Cement quality tests, which were assessed by measuring the compressive strength, implied that TIPA had the highest improvement in 28-days strength with 18.8% at 700 g/t where 8.9% and 5.6% increase were achieved for glycol-based and TEA-based grinding aids respectively. As a conclusion of the study, TIPA based grinding aid was found to be the most effective one for dry stirred mill application of cement due to its provided operational benefits and quality improvements.

1. Introduction

Dry energy intensive processes, such as cement manufacturing, demand efficient grinding technologies to reduce the energy costs where inefficient ball milling technology is still in use. Development of stirred media mills improved the energy utilization in fine grinding area when compared to conventional ball milling. There have been studies compared the energy utilizations of both technologies, which reported that stirred milling is more energy efficient [1,2]. This can be attributed to having higher media filling ratio, agitating the fine media at higher tip speeds hence having higher power utilization per unit volume [3].

When cement grinding operation is considered, there is a ball mill and air separator operated in closed circuit to achieve required fineness. Within the circuit, high amount of material is circulated back to the mill owing to its coarseness. This coarse product can be ground with an efficient milling technology, such as stirred milling, hence the production rate of the circuit could be increased. Some other applications could be the use of the stirred mill on electro filter product and final product streams with the aim of improving the quality (ultimate strength) of the finished product as well as energy efficiency [4]. Pilot scale dry horizontal stirred mill was developed for this purpose with the partnership of Netzsch-Feinmahltechnik GmbH. The mill was tested in cement grinding area at different operating conditions and design features [4,5]. Moreover, tests were performed at different types and dosage rates of grinding aids, which was investigated within the scope of this paper. Grinding aids have been used in cement grinding applications for many years and literature reports energy saving operations when they are utilized [6,7]. They are mostly organic compounds and commonly consist of glycols, alkanolamines and phenols [8]. The high polarity in their chemical functioning groups of –OH, –NH2, –COOR, –SO3–, causes the tendency to adsorb on electrostatic surfaces from fractured covalent bonds of Ca-O, Al-O, and Si-O, and to resist the agglomeration [9]. The selection of the grinding aids depends on several parameters e.g., the benefits on overall specific energy consumption, cement strength, surface area development etc. and Toprak et al. [6], in their studies compared several types of grinding aids and concluded that each of them has varied influences on the process and product quality.

Up to date, the grinding aids have been used in stirred milling applications as well. Zheng et al. [10] tested various types of them in limestone grinding and concluded that the surface area of the product could be doubled with the use of proper grinding aid. Choi et al. [11] in their stirred mill test works showed that it was possible to reduce the utilized energy by 37% with the use of grinding aids. Within the context of the study, 3 types of grinding aids (glycol, TEA and TIPA) were tested and the influences on mill performance and product quality were discussed by considering the differences in the agglomeration energies and adsorption mechanisms reported in the literature. The study

* Corresponding author.
E-mail address: okyaltun@hacettepe.edu.tr (O. Altun).

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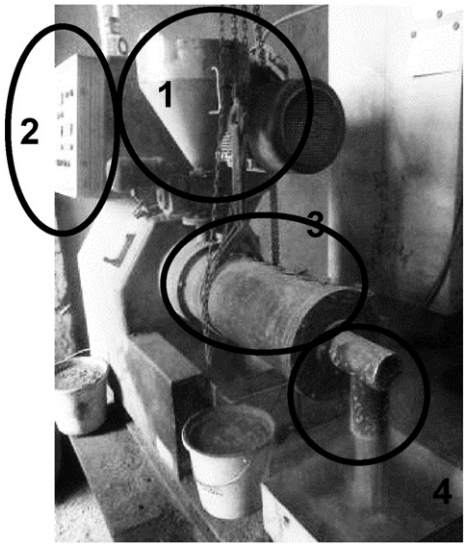

Fig. 1. Dry horizontal stirred mill (1-feed hopper, 2-control panel, 3-grinding chamber, 4-product outlet).

is thought to be beneficial for the development of proper grinding aids particularly for dry horizontal stirred mill employed in cement grinding.

2. Materials and methods

2.1. Description of the mill setup

The photograph of the mill used in this study is depicted in Fig. 1 where the key components are also illustrated such as control panel, feed unit (feed hopper and rotary valve), grinding chamber and product discharge. In addition, Table 1 gives the technical data of the mill.

The rotary valve mounted under the feed hopper adjusts the mill feed rate, which is measured from the product outlet by cutting the material flow. A torque sensor installed measures the power draw of the mill, which displays on the control panel instantly. In grinding operation of the mill, air is supplied from the feed inlet in order to improve material transportation towards the discharge end. The ground particles leave the mill from the product outlet where a product separator exists with the aim of retaining the media inside. Product separator is a cage having openings smaller than the bead size and attached to the discharge end of the mill directly as illustrated in Fig. 2.

The temperature is important parameter that should be controlled in cement manufacturing. Therefore, the measurements were undertaken via infrared or non-contact thermometer from the outside of the mill discharge end. Such information was used to identify if the product of the stirred mill was in acceptable temperature limits [12].

2.2. Grinding aids

Although various types of grinding aids are utilized by the industry [6,13] within the scope of the study, 3 types of them were tested for dry stirred milling which were; TEA, TIPA and Glycol-based ones. The grinding aids tested were in liquid form and mixed with feed material

Table 1
Technical specifications of the mill.

Effective diameter (cm)	26.4
Effective length (cm)	75.0
Motor power (kW)	18
Maximum feed rate (kg/h)	500
Stirrer tip speed (m/s)	1.08 - 9.76
Maximum air flow rate (L/h)	1000

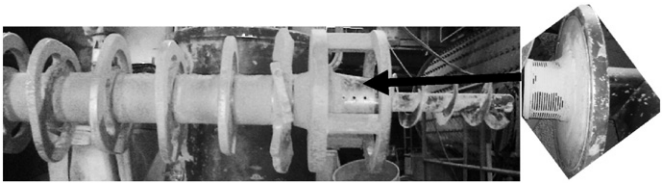

Fig. 2. Discharge end of the mill with the product separator.

Table 2
The milling conditions of the initial test studies.

Media Type	steel
Media size (mm)	4
Stirrer design	disc
Stirrer speed (m/s)	5.42
Media filling (%)	60
Feed rate (kg/h)	400

in the hopper before being ground. The tests were performed at different dosage rates, which were 500–700–1000 g/t, and at the same milling conditions given in Table 2, so that the variations coming from the operational changes were minimized.

This study assumed that the mill feed and product samples had the same amount of grinding aids that means the given dosage rate was fully adsorbed by the material. Therefore, no measurements were undertaken on how much of the grinding aids were absorbed by the product.

2.3. Material characterization

The feed sample together with the test products were characterized regarding to their size distribution curves, specific surface area and cement properties. In this context, Sympatec laser sizer (Germany) having size measurement range between 1.8 μm and 500 μm was utilized in dry mode then the whole distribution from top size down to 1.8 μm was determined. The size distribution curves were used to determine the slope and the mean size parameters. The slope, which was expressed by n parameter in RRBS equation, is an important parameter in cement strength development [14] and within the study the influences of stirred milling were discussed. Specific surface area measurements were undertaken via Blaine method [15]. Moreover, cement strength at different ages (7 days and 28 days) and water demands of cement mortar were determined at the cement plant by applying the standard procedures [16].

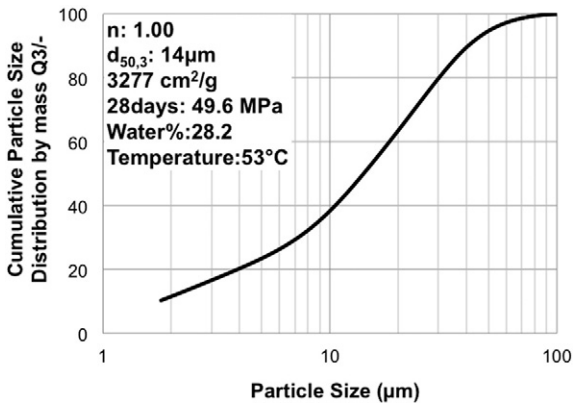

Fig. 3. Feed material characteristics.