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The effects of chamber diameter and stirrer design on dry horizontal stirred mill performance

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ABSTRACT

This paper focussed on investigating the effects of chamber diameter and stirrer design on cement grinding performance of a horizontal type dry stirred mill. Within the scope, pilot scale test works were undertaken with two different chamber diameters (20.4 cm and 26.4 cm) having the same length and three different stirrer designs (wing, cross and disc) having the same diameter (16 cm). The chamber diameter tests were performed at the same stirrer design, media size and media filling. The studies concluded that, the use of larger chamber improved the grinding efficiency since 31.8% and 35.8% less energy was consumed than the smaller mill at the RR_{d50} of 1.41 and 1.66 respectively. This behaviour of the larger mill can be attributed to the increased gap distance between the chamber wall and stirrer edge. With regards to stirrer design, the statistical evaluations, grinding results and temperature measurements all indicated that the disc design of stirrer ground the particles more effectively at high energy levels (>40 kW h/t). The use of the disc design reduced the energy consumption by 21% (at RR_{d50} of 3.5). This was attributed to dissipation of energy as heat since the temperature measured for the wing and cross types were higher than the disc type.

1. Introduction

The idea of developing dry horizontal milling came from increasing demand on energy efficient grinding machines for cement grinding operation, which is an energy intense process. Altun (2013) in his PhD study conducted pilot scale test works with this grinding machine where the effects of operating conditions and design parameters (chamber diameter, stirrer design) were investigated. Within the scope of the paper, the effects of chamber diameter and stirrer design on the cement grinding performance of the dry horizontal stirred mill are to be presented. The influences of these parameters were investigated in wet stirred milling studies. Kwade and Stender (1998) and Stender et al. (2004) discussed the effects of different chamber sizes and concluded that the use larger mill reduced the energy utilization at the same product fineness for a given media size. The effects of stirrer design were studied by Stehr (1988) and Kwade (1999) who pointed out that pinned design stirrers had higher power densities than the disc design.

For the dry horizontal stirred mill, 2 chamber diameters (20.4 cm and 26.4 cm) with the same length and 3 stirrer designs (disc, cross and wing) having the same diameter (16 m) were tested. The performances were compared by considering power draw measurements, energy consumptions, size distribution analyses and mill chamber temperature measurements which are presented in the following sections. The results obtained in this study were discussed with the literature.

2. Materials and methods

2.1. Description of the experimental apparatus

The structure of the mill is similar to IsaMill (Clark, 2007) and the key components are control panel, feed unit (feed hopper and rotary valve), grinding chamber and product discharge (Fig. 1). The technical specifications of the mill are given in Table 1.

For the dry horizontal stirred mill, the feed rate to the mill body is adjusted via changing the speed of rotary valve placed under the feed hopper. The throughput of the grinding operation is measured from the product outlet by cutting the material flow. The power draw of the mill, which displays on the control panel instantly, is measured by a torque sensor installed to the mill. In grinding operation of the mill, the material to be ground flows from feed hopper into the grinding chamber by gravity and at the same time air is supplied from the feed inlet in order to improve material transportation

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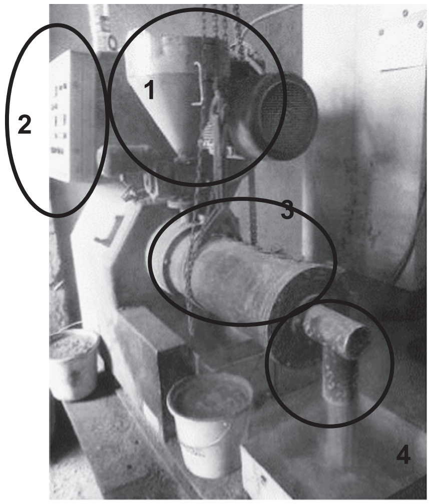

Fig. 1. Horizontal stirred mill on the left (1 – feed hopper, 2 – control panel, 3 – grinding chamber, 4 – product outlet).

Table 1
Technical specifications of the dry stirred mill.

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

towards the discharge end. The ground particles leave the mill chamber 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.

2.2. Material and milling conditions

The material used for the grinding tests was collected from final product and separator reject streams of a cement grinding circuit during CEM I 42.5R type cement production. The particle size distributions and the fineness parameters e.g., mean size and Blaine, are given in Fig. 3 and Table 2 respectively. Within this study, final product material was used in testing chamber diameters and the separator reject material was used for testing different stirrer designs.

Chamber diameter and stirrer design test works were performed under the milling conditions given in Table 3. Grinding chemical, which was in liquid form, was used throughout the studies with the aim of improving particles' transportation towards the product outlet.

2.3. Characterization studies

The collected samples from the test studies were subjected to characterization studies. In terms of characterization, the size distribution and Blaine measurements were undertaken via Sympatec laser sizer (Germany) and Atom Teknik (Turkey) devices. Both measurements were used in calculating reduction ratio (RR) and surface area development (Eq. (1)) of the grinding process and then correlated with the energy consumption.

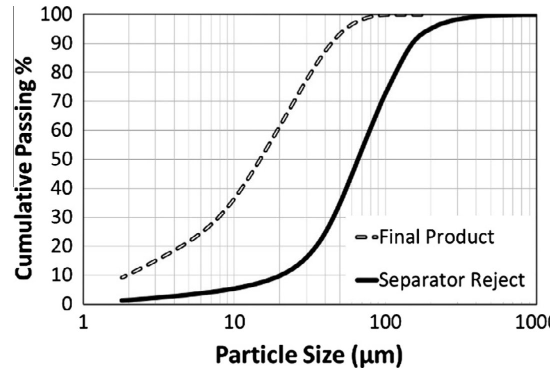

Fig. 3. Particle size distributions of the materials used in the grinding tests.

Table 2
Fineness parameters of the materials used.

	Final product	Separator reject
d_{50} (μm)	15	66
d_{80} (μm)	32	121
Blaine (cm^2/g)	3277	710

Table 3
Milling conditions of the grinding tests.

Media material	Steel
Stirrer material	Steel
Chemical dosage (g/t)	700
Air flow rate (L/h)	1000

$$\text{Surface area development } (\Delta S) = \text{Product Blaine} - \text{Feed Blaine} \tag{1}$$

3. Results and discussion

3.1. The effects of chamber diameter

In this section, the comminution results obtained from 2 chambers having different diameters are presented. The dimensions of both chambers used in test studies are given in Table 4. Throughout the test studies final product material (Table 2) was ground, the media composition of 60% 4 mm and 40% 3 mm was charged and the disc stirrer design (16 cm in diameter) was preferred. As can be understood, only the mill chamber was changed to examine the effects on grinding performance. Table 5 presents the test plan.

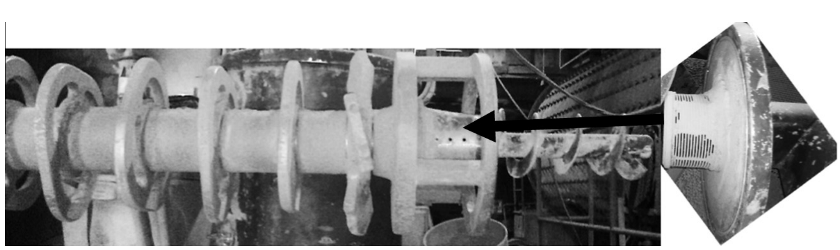

Fig. 2. Discharge end of the mill with the product separator.