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Investigating multicomponent breakage in cement grinding

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ABSTRACT

The production of blended cements involves grinding raw materials such as cement clinker, pozzolan, blast furnace slag, limestone and gypsum, within the same mill. This is known as intergrinding. However, it is not possible to control the product fineness of each component separately in the multicomponent system and this results in overgrinding of relatively softer components. Since each component exhibits different breakage characteristics, the fineness of the components around the closed grinding circuit will vary depending on relative grindabilities and the overall fineness of the cement will then depend on the ratio of the components in the blend with different grindabilities. This paper aims to examine the size by mass distribution of each component around a closed circuit ball mill during cement production by intergrinding. For this purpose, a ball mill with an air classifier in a cement plant was sampled and size by assay analyses of the samples was carried out to calculate the particle size distribution of each component around the circuit. The results indicated that the size distributions of the components in each stream vary depending on their grindabilities and the final product comprises components with different fineness. The breakage rates of the components were calculated and it was seen that the breakage rates of the relatively softer components are higher than that of harder ones.

1. Introduction

For cost-effective operation in cement milling, materials exhibiting cementitious properties are partially replaced with cement clinker and the product is known as blended cement. The amount and the type of the materials replaced with cement clinker determine the quality of the final product and it is referred to European Standard for Cements (EN 197-1). In addition to cement clinker and gypsum which are the main components of the ordinary Portland cement, pozzolans, blast furnace slag and limestone are the other components in blended cement production. During the blended cement production the components are ground within the same mill and as a result of different grindabilities, relatively harder components accumulate in coarser fractions while the softer ones accumulate in finer fractions (Schiller, 1992; Tsivilis et al., 1999). Hence, the control of the fineness of the components independently is impossible and this leads to overgrinding. However, in some applications, separate grinding of the harder components such as blast furnace slag is employed and then subsequent mixing takes place for blended cement production. In this case, subsequent mixing requires more attention for the final product quality that influences the compressive strength. Although separate grinding gives an opportunity to optimize the product quality and power consumption by controlling the product size distribution (Müller-Pfeiffer et al., 2000), intergrinding takes over in cement grinding due to its simplicity and low investment cost.

Grinding a mixture of components with different grindabilities has been studied by several researchers and the main aim of the studies was to investigate the interactions between the harder and softer component. Most of the published works in literature involves the grinding of mono-size components in a binary mixture and alone in a laboratory scale mills, and the results were discussed in terms of grinding kinetics and specific grinding energy. Somasundaran and Fuerstenau (1963) showed that the energy consumed by limestone is higher than that by quartz when they are ground together. Venkataraman and Fuerstenau (1984) carried out batch and locked-cycle tests on the binary mixtures of calcite, hematite and quartz, Fuerstenau and Venkataraman (1988) worked on quartz-calcite mixture and in both studies results of the kinetic grinding tests showed that the breakage rate of the softer component is improved with the presence of harder component in the binary mixture. Later studies by Kapur and Fuerstenau (1988) and Fuerstenau et al. (1992) proposed the energy split factor which is used to estimate the energy consumed by each component in binary-mixtures. Venkataraman and Fuerstenau (1984) and Tavares and Kallemback (2013) carried out locked-cycle tests and the results showed that the harder component accumulates in

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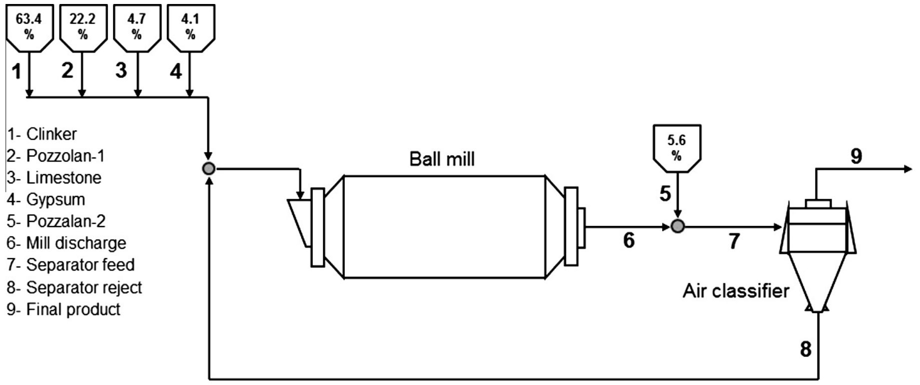

Fig. 1. Simplified flowsheet of the cement grinding circuit and sampling points.

the mill load as it is concentrated in the circulating load. Hosten and Avsar (1998) carried out batch tests on cement clinker and trass which is a type of pozzolan, and observed that the relatively harder clinker particles increases the breakage rate of the trass in the mixture. Binary mixtures of quartz, kaolin and K-feldspar were used for batch tests by Ipek et al. (2005a) and ternary mixtures of quartz, kaolin and K-feldspar for −3.35 + 2.36 mm fraction was tested by Ipek et al. (2005b). Not only was the laboratory scale ball mill used during the studies; Cho and Luckie (1995) used a ball-race mill, which is similar to Hardgrove machine in terms of grinding action, in order to grind binary mixtures of quartz, bituminous coal and anthracite. Abouzeid and Fuerstenau (2009) carried out tests on limestone and quartz mixture using lab-scale high pressure grinding rolls to investigate the mill performance under multicomponent breakage conditions. In addition to lab-scale tests, Weller et al. (1988) published results from copper ore grinding in pilot-scale and small continuous mills running with hydrocyclones.

Table 1
Size fractions prepared for component analysis.

	Fresh feed	Mill discharge	Separator feed	Separator reject	Final product
Head sample	✓	✓	✓	✓	✓
−50 + 9.5 mm	✓	–	–	–	–
−9.5 + 0.150 mm	✓	✓	✓	✓	–
−0.150 + 0.075 mm	✓	✓	✓	✓	✓
−0.075 + 0.032 mm	✓	✓	✓	✓	✓
−0.032 + 0.020 mm	✓	✓	✓	✓	✓
−0.020 mm	✓	✓	✓	✓	✓

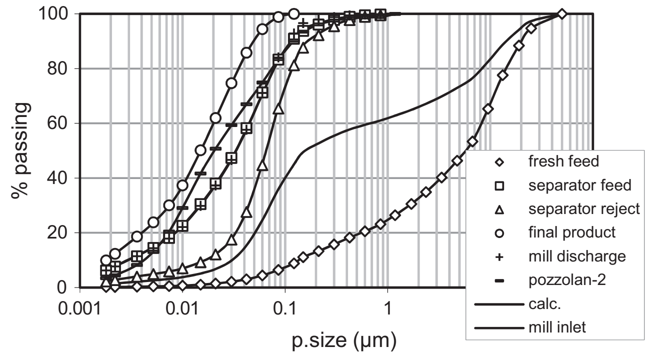

Fig. 2. The calculated and measured size distributions of the streams around the circuit.

This paper presents the results of component analysis around the cement mill during quaternary-mixture grinding of cement clinker, pozzolan, limestone, and gypsum for blended cement production.

2. Sampling and experimental studies

A sampling campaign was performed around the cement grinding circuit, during the CEM II B-M (P–W) 32.5R type blended cement production. In accordance with EN 197-1, CEM II B-M (P–

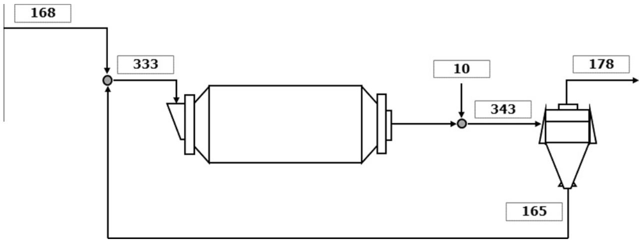

Fig. 3. Calculated flowrates (tph) around the circuit.

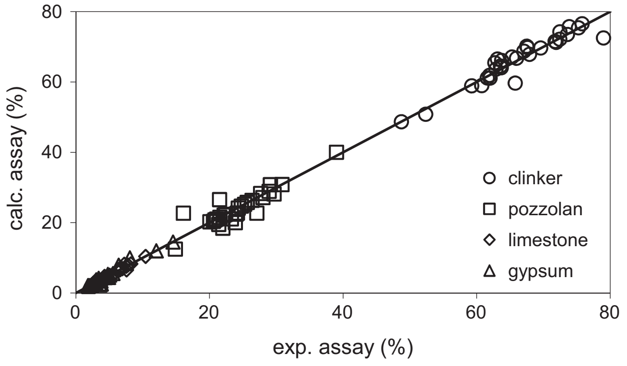

Fig. 4. Agreement between the experimental and calculated assays.

Table 2
Measured and calculated input/output rates of the components.

Component	Measured input rate (%)	Calculated output rate (%)
Clinker	63.4	64.1
Pozzolan	27.8	25.3
Limestone	4.7	6.2
Gypsum	4.1	4.4
Total	100.0	100.0