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Full Length Article

Experimental investigation of breakage and energy consumption characteristics of mixtures of different components in vertical spindle pulverizer

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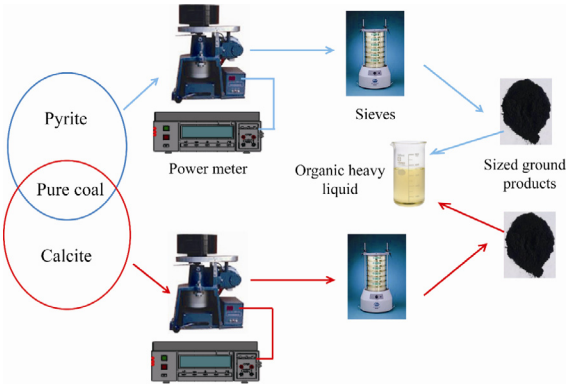
HIGHLIGHTS

- Heterogeneous grinding of binary-mineral mixture is conducted in Hardgrove machine.
- Analyses of breakage behavior of the mixture and each component.
- Hardness index is modeled into the breakage model.
- Analyses of energy split based on the modified model and energy-size data.

GRAPHICAL ABSTRACT



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ABSTRACT

Complex interactions among components in the heterogeneous grinding have an influence on breakage and energy consumption characteristics of components in mixtures if compared with the single breakage. In this paper, a modified Hardgrove mill, with the addition of a power meter, is used to simulate the grinding process of vertical spindle pulverizer. Binary-component mixtures of coal and pyrite, or coal and calcite, in the size of −2.8 + 2 mm, are prepared to study the heterogeneous breakage. For the mixture A of coal and pyrite, the fineness of pyrite progeny is higher than that from single-breakage. Instead, the coal in mixture A shows the opposite trend. Because of the relatively less difference in hardness between coal and calcite, size distributions of components are environment-independent. Breakage of mixture follows the first-order kinetics, as well as each component in mixtures. In order to describe the energy-size reduction of mixture, a modified model in the form $t_{10} = A(1 - e^{-b \cdot E_{CS}/H_W})$, has been derived from modeling the mass weighted hardness index of mixture, and its predictions are highly fitted with experimental and supplemental data. In addition, energy split phenomena of components are discussed qualitatively using the modified model. Specific energies that need to yield the same product t_{10} of one component both in the single and mixture breakage are compared, and the interaction of one component on the breakage of

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Nomenclature

t	grinding time	E_{CS}	mass specific grinding energy
s	specific rata of breakage of particles in initial size	A, b	ore impact breakage parameters
$w_1(t)$	mass fraction of unbroken particles in the top size after grinding for t seconds	H_w	mass weighted index of the mixture
		x	geometrical mean size of feed
$w_1(0)$	mass fraction of unbroken particles in the top size at the initial stage	t_n	cumulative yield passing a given fraction of x/n
		n	breakage ratio
t_{10}	mass percent of ground products in size of less than 1/10th of initial geometrical mean size of feed	α	fitting parameters of size distribution curves

another one in mixture grinding also has been analyzed. Size distributions of ground products using t_{10} are well predicted, which are critical to conduct the computation of size distribution of progenies at given specific energies.

1. Introduction

Comminution plays important roles in mineral beneficiation, cement preparation, and pulverizing raw coal in power plants. Breakage of raw coal in vertical spindle pulverizer (VSP) is extremely essential to yield the pulverized fuel (PF), which should be fine enough for the effective combustion in boilers. In 2010, nearly 40% of world electricity was generated by coal-fired plants [1]. Meanwhile, more than 80% of Chinese electricity is produced by coal-fired plants [2] and over 1.6 billion tons of raw coal are consumed every year. It has also been reported that about 0.5–1% of the gross electrical power from coal-fired plants is consumed for the breakage of raw coal in the pulverizing system [3–5]. Comminution consumes such large amounts of energy, therefore, researches for better understanding of breakage and energy consumption characteristics, which can help to evaluate and improve the energy efficiency of comminution processes, are needed.

In China, VSP is widely used in coal-fired plants. The structure of E type VSP is shown in Fig. 1, and arrows in this figure clearly indicate the moving trajectory of coal in it. Raw coal is fed onto the grinding table and fills the space among media. After broken by heavily loaded grinding rollers, generated fines are discharged from the rotated table. Then, the coal powder, carried in the hot primary air, passes through the elutriator and classifier in sequence, where ground products are separated based on differences in particle size. Coarse particles rejected by elutriator and classifier return to the table for regrinding and qualified PF enters boiler for combustion. As the maximum size of raw coal is over 50 mm, breakage ratios are in the range from 200 to 1000. The ideal fineness indices of PF is less than 5% greater than 0.2 mm and less than 16% greater than 0.09 mm [6]. However, industrial researches on VSP show that the mass ratio of circulating materials rejected by classifier to feed ranges from 8:1 to 12:1, and more than 80% of circulating materials are in size of −0.2 mm [7]. On the other hand, size reduction of particles results in the liberation of minerals from coal. Wide size distribution, which is caused by the breakage of raw coal and supplement of new feed and circulating materials, and liberation of associated minerals make the particle breakage in VSP heterogeneous. Hence, as a first step towards understanding interactions among different components, heterogeneous grinding of mixtures is conducted. It will be a useful and essential prerequisite for the study of breakage characterization of mineral mixtures and particles in different sizes.

Note that heterogeneous grinding is very common in comminution industries, and uncertain interactions among components usually occur [8], which makes the breakage behavior and energy consumed characteristics of components complex. Studies about the energy-size reduction of mixtures in different volumetric ratios of components, or particles in various size fractions, have been conducted on ball mills by Fuerstenau and co-workers [9–14].

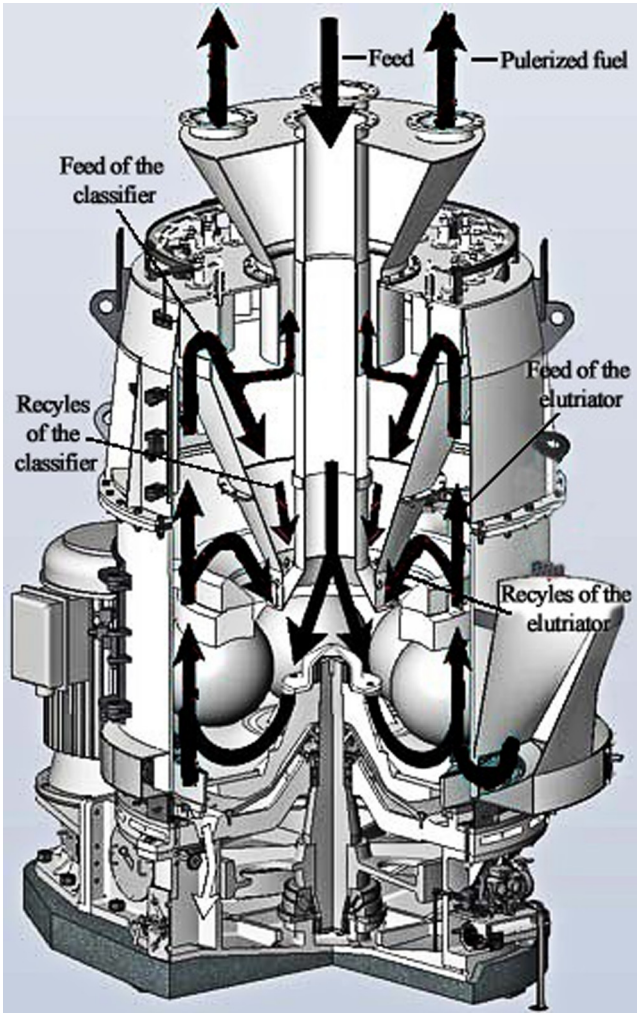

Fig. 1. Structure of E type VSP used in power plants.