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Dynamic characteristics of an equal-thickness screen with a variable amplitude and screening analysis

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ABSTRACT

Screening is the key unit in coal processing and utilization. Recently, equal-thickness screens characterized by a large capacity and high efficiency have been extensively used. Conventionally, equal-thickness screening is achieved by changing the inclinations of each stage or adjusting the exciting force. In this paper, a single-deck equal-thickness vibrating screen (ETVS) driven externally by an unbalanced two-axle excitation with a large span is proposed, and a set of dynamic equations governing the motion of the screen are also presented. The vibration data was obtained using a vibration test and analysis unit, and the bed stratification and particle behavior on the screen were obtained by image acquisition using a high-speed camera and data analysis unit. Screening experiments were conducted to evaluate the classification performance of the ETVS with a variable amplitude. The amplitude of the ETVS showed a decreasing trend, and a constant bed thickness was obtained throughout the screen deck. The ETVS has advantages of a high screen deck utilization and an efficient classification. Compared to the normal vibrating screen (NVS), the screening efficiency of the ETVS increased by 3.05%–8.76%. The screening performance of the ETVS is obviously better than that of the NVS, especially when dealing with a large amount of materials and those with high moisture.

1. Introduction

Coal, an important primary energy source, accounts for approximatively 30% of the world's energy resources [1–3]. Coal preparation is the basis and prerequisite for clean coal utilization [4–6], energy conservation, and sustainable development, as well as the most cost-effective method for clean coal technology [2,7–9]. Screening is an indispensable unit operation in coal preparation and widely used for classification, predesliming, product dehydration, and medium draining [10–13]. Efficient screening not only saves the cost of coal preparation, optimizes product structure, and increases economic benefits, but also improves the energy efficiency and reduces carbon dioxide emissions, consistent with the development goal of coal industry [14,15]. In the recent years, banana vibrating screens characterized by a large capacity, high efficiency, and reliable performance have been extensively used with the extension of heavy-medium separation and construction of large-scale coal preparation plants. Several studies on screening theory, structure design and parameter optimization by theoretical analysis, numerical simulations, and pilot plant tests have been reported [11,12,16–19].

Equal-thickness screening is a sieving method that provides a constant bed thickness on a multistage screen throughout screening. This is achieved by adjusting the acceleration or gradient of each screen stage to ensure a consistent thickness from the feed end to the discharge end. The equal-thickness screening of aggregates can be achieved by either changing the inclinations of each stage or adjusting the exciting force. Dong et al. [18] reported that particle accumulation is affected by the motion of particles on a multistage banana vibrating screen according to the partition curves and distribution of percentage passing. Specifically, an appropriate particle velocity contributes to the percentage passing, and a low velocity generally causes accumulation. Cleary et al. [16,17] reported that the motion for a moist feed on the screen is determined by the particle-size distribution and its viscosity. These are obtained from the relationship between the bed stratifying on the double-deck banana vibrating screen and passage of particles through the screen with peak accelerations. Fernandez et al. [19] determined the effects of the thickness and density of bed on the particle flow behavior based on a wet screening on a double-deck banana vibrating screen. Zhang et al. [20] established a dynamic model with three degrees of freedom for a three-axis equal-thickness screen with a variable trajectory, and a set of differential dynamic equations of the centroid of the screen box were simulated and calculated, as well as the motion equations of an arbitrary position on the screen box. Liu and Wang

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et al. [21] investigated the dynamic characteristics and classification performance of a four-axis banana vibration screen with a variable trajectory and obtained a screening efficiency of 94.01%. A multistage banana vibrating screen has characteristics of a satisfactory classification performance and high capacity, but the complex construction, a large floor area, and structural vulnerability lead to limitations. The dynamic characteristics of a multiaxis banana vibration screen contribute to a good classification result, but the complex exciting structure and dynamic stress of the screen make it less reliable.

In this paper, a single-deck equal-thickness vibrating screen (ETVS) driven externally by an unbalanced two-axle excitation with a large span is proposed to simplify the exciting system of a multistage screen with a variable inclination. Using a vibration test and high-speed camera, the amplitude fluctuation and material distribution on the screening surface were analyzed to elucidate the screening mechanism of the single-deck ETVS. Thus, the advantages of an ETVS with a variable amplitude over a normal vibrating screen (NVS) were determined by comparing their screening performances.

2. Experimental

2.1. Experimental system

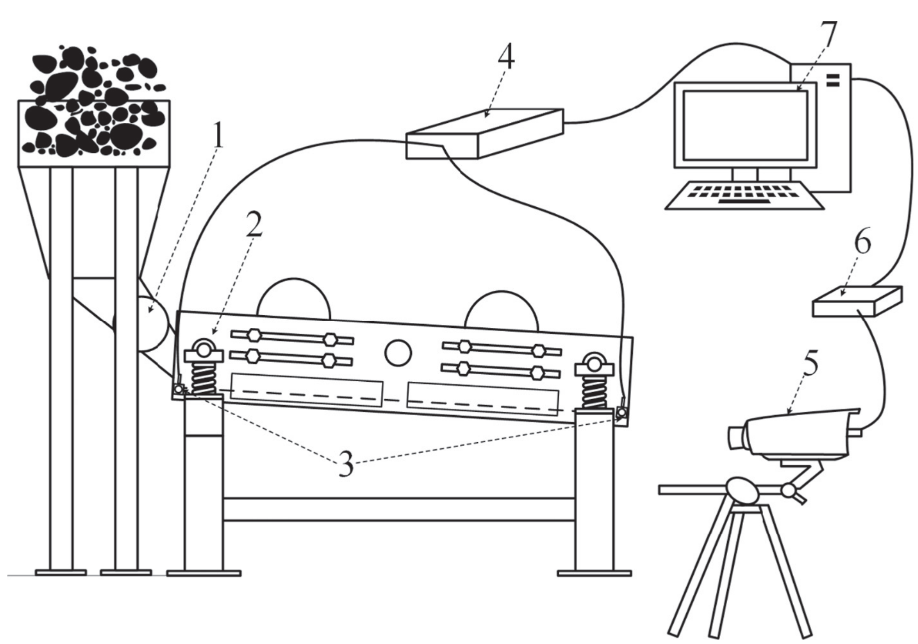
The screening test and data acquisition system is shown in Fig. 1. It consists of a feeder, vibrating screen, vibration test and analysis unit, high-speed camera for image acquisition, and data analysis unit. The vibrating screen consists of exciting motors and bridges, reinforced beams, a sieve box, a screening surface, a spandrel girder, damping springs, and stents. The screening surface has an open area of 51.01% and 0.6 m in width and 1.2 m long. Each sieve pore has a diameter of 15 mm and equipped with a diamond array. The exciting force on the feed end is controlled by the angle between the two eccentric blocks of the exciting motor, and the span between the motors is adjusted by the position of excitation bridges. The vibration test and analysis unit consists of several triaxial acceleration transducers, a data acquisition device, and a multichannel signal acquisition unit equipped with an analysis software and computer for the acquisition, multiplication, storage, and analysis of acceleration signals collected from the test points arranged on the screening surface. The high-speed camera and data analysis unit consists of an I-SPEED3 high-speed camera, a controller, and the I-SPEED Suite software; this is used to record and evaluate the behavior of particles during the screening. The operating parameters for this experiment are shown in Table 1, where α is the inclination of the screen deck (°), Q is the feed rate (t/h), L is the distance between two vibration exciters (mm), f_1 and f_2 are the exciting force on the feed and discharge ends, respectively (KN), and $k_f = f_1/f_2$ is the unbalanced coefficient of the exciting force.

Table 1
Operating parameters of screens.

Vibrating screen	α (°)	Q (t/h)	L (mm)	f_1 (KN)	f_2 (KN)	$k_f = f_1/f_2$
NVS	15	7.20	300	3.6	3.6	1.00
ETVS	15	7.20	540	3.6	4.4	1.23

2.2. Materials

The particle-size distribution and moisture content of the coal samples are obtained from Xuzhou, Jining and Ordos respectively are shown in Table 2. The dominant particle size fractions are 25–6 mm for Xuzhou sample, 50–6 mm for Jining sample and the particle size of Ordos sample is uniform. The moisture of Ordos sample is relatively higher than that of Xuzhou and Jining samples, which will affect the screening performance. The cumulative curve can be drawn as shown in Fig. 2 based on Table 2. When the classification size is 13 mm, the size fractions of fine particles, near-aperture particles, hindered particles and coarse particles are 9.75–0 mm, 13–9.75 mm, 19.5–13 mm and 50–19.5 mm respectively. Therefore, the particle types and size characteristics of coal samples can be further obtained according to Fig. 2, as shown in Table 3. In addition to the near-mesh particles is different to pass through the screen aperture, the hindered particles prevent the passage of material through the bed and aperture. All of this result to a bad classification performance. It can be known that the near-mesh and



1-Feeder, 2-vibrating screen, 3-acceleration transducers, 4-data acquisition device;

5-high-speed camera, 6-controller, 7-computer and analysis software

Fig. 1. Screening test and data acquisition system.