Fuel 194 (2017) 329–338

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

Process analysis and operational parameter optimization of a variable amplitude screen for coal classification

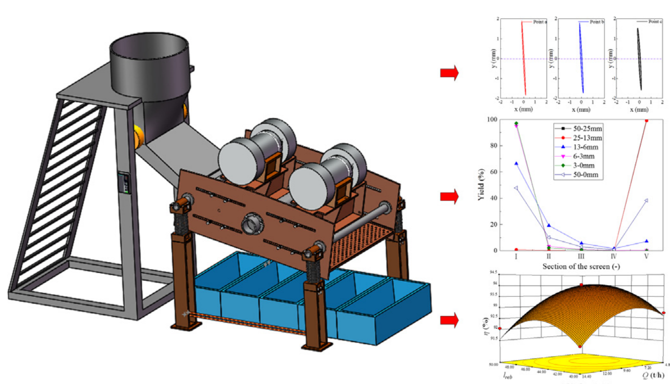
Haishen Jiang, Yuemin Zhao *, Jinpeng Qiao, Chenlong Duan *, Zengqiang Chen, Enhui Zhou, Hairui Diao, Dahai Zheng

Key Laboratory Coal Processing and Efficient Utilization of Ministry of Education, China University of Mining and Technology, Xuzhou 221116, China
School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou 221116, China

HIGHLIGHTS

- A variable amplitude screen was proposed for classification of coal.
- Kinematic characteristics and screening process analysis of a VAS were studied.
- BBRSM was used to analyze the influencing degree of various operating factors.
- The optimal operating conditions were validated by sieving test.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 1 July 2016
Received in revised form 25 December 2016
Accepted 27 December 2016
Available online 13 January 2017

Keywords:
Variable amplitude screen
Coal classification
Process analysis
Operating parameters
Response surface methodology

ABSTRACT

Screening is an indispensable unit operation for the large-scale separation of materials. A variable amplitude screen (VAS) has a high screening efficiency and reliable performance in coal beneficiation and is widely used for coal classification. In this study, the kinematic characteristics and process analysis of a novel VAS for coal classification were investigated. The vibration test results show that the y axes amplitudes of acceleration and displacement gradually decreased along the material flow. This strengthened the loose and stratification of materials and improved the screening efficiency (η) of the VAS. Furthermore, the effects of several operating factors on the screening performance were studied using Box–Behnken response surface methodology (BBRSM). Based on the experimental data and analysis results, the quadratic model was selected to describe the relationship between η and the operational factors; the sequence of the influencing degree of various factors on η was $\alpha > Q > k_f > l_{reb}$. The optimal operating conditions were obtained by BBRSM analysis and verified by screening experiments, and the actual screening efficiency was 97.18% when the operating conditions were $\alpha = 15°$, $k_f = 1.19$, $l_{reb} = 47.54\%$ and $Q = 10.12$ t/h, indicating the satisfactory screening performance of coal in a VAS.

1. Introduction

Coal, an important primary energy source, accounts for 30% of the world's energy resources [1–9]. This is one of the main energy resources in China and provided 64% of the total energy

* Corresponding authors at: School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou 221116, China.
E-mail addresses: ymzhao_paper@126.com (Y. Zhao), clduan@cumt.edu.cn (C. Duan).

http://dx.doi.org/10.1016/j.fuel.2016.12.091

consumption in 2015 [10–12]. Coal beneficiation is the basis and prerequisite for clean coal utilization as well as the most cost-effective method for clean coal technology [13–21]. Screening is an indispensable unit operation in coal beneficiation [20–26]. Efficient screening saves the cost of coal beneficiation, optimizes the product structure, and improves the energy efficiency [25–28]. A variable amplitude screen (VAS) has a high screening efficiency and reliable performance and is widely used for coal classification [29,30]. Ma et al. [29] reported that the VAS made the particles at the front of the screen rapidly thrown up and moved back and can provide a reference for solving the retention problem of materials at the screen front. Liu et al. [30] 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%, indicating a good screening efficiency.

Many operating parameters such as the aperture of the sieve, mesh size of the sieve, screen surface inclination, screen length and width, amplitude and frequency, and feed rate significantly affect the performance of screening operation [24,27,31–35]. Tung et al. [36] focused on the influence of a woven-mesh structure in batch screening investigations. Zhao et al. [37] studied the effects of vibration amplitude, throwing index, and screen inclination on the screening efficiency of a circularly vibrating screen and proposed optimal operating issues. Dong et al. [35,38] reported a numerical study on the flow of particles on a banana screen as a function of vibration parameters including frequency, amplitude, and type of vibratory motion.

In this work, the particle distribution characteristics and screening performance of coal in a VAS were studied. Moreover, the significance of the effects of various operating factors on the classification performance of coal was investigated using the Box–Behnken response surface methodology (BBRSM), and the optimum parameters were validated using a sieving test.

2. Experimental

2.1. Apparatus

The schematic diagram of the VAS system is shown in Fig. 1. It mainly consists of a silo, feeder, VAS, receiver, and frequency converter. The VAS consists of exciting motors, excitation beams, reinforced beams, a sieve box, a screening surface, damping springs, and stents as shown in Fig. 1. The exciting motor was used to provide the exciting force for the vibrating screen. The excitation beam is used to mount the excitation motor. The screen box composed of side plates, reinforced beams and spandrel girders was used for the installation of the screen surface and provide space for the material screening. The screen surface was used for the classification of materials according to the size of screen aperture. The stents were mainly to support the screening box. The damping springs were mainly to play the role of vibration isolation in order to reduce the vibration load transmitted to the ground. The silo was used to store the screening material. The speed of the feeder was adjusted using a frequency converter to control the amount of material in the unit time supplied to the VAS. The receiver was divided into five sections to collect the oversized and undersized products.

2.2. Materials

The particle distribution as well as the moisture and ash content of the coal sample obtained from Zhangji mine, Xuzhou China is shown in Fig. 2a. The dominant size fraction 13–6 mm constitutes 50%, and the moisture content of each grain size of coal was low. Therefore, the effect of moisture on the screening effect is very weak. Moreover, a smaller particle size indicates a lower ash content. The size fractions of the fine particles, near-aperture particles, hindered particles, and coarse particles were 9.75–0 mm, 13.00–9.75 mm, 19.50–13.00 mm, and 50.00–19.50 mm when the designated size was 13 mm. Therefore the diameter of screen aperture is selected as 15 mm according to the principle of probability sieving, and the screening surface has an open area of 51.01%, 0.6 m in width and 1.2 m long. The corresponding yields of particles were shown in Fig. 2b, the near-aperture and hindered particles account for a large share of ~50% of the sample, thus easily deteriorating the stratification of particles and causing screen blinding.

2.3. Evaluation

Some mismatches usually exist in the oversize and undersize during the screening process. The screening efficiency and total misplaced materials were used to evaluate the screening performance in this paper; they can be calculated using Eqs. (1) and (2), respectively [26].

$$\begin{cases} E_c = \frac{\gamma_o \times O_c}{F_c^r} \times 100 \\ E_f = \frac{F_f^r - \gamma_o \times O_f}{F_f^r} \times 100 \\ \eta = E_c + E_f - 100 \end{cases} \quad (1)$$

$$\begin{cases} M_c = 100\gamma_u U_c \\ M_f = 100\gamma_o O_f \\ M_O = M_c + M_f \end{cases} \quad (2)$$

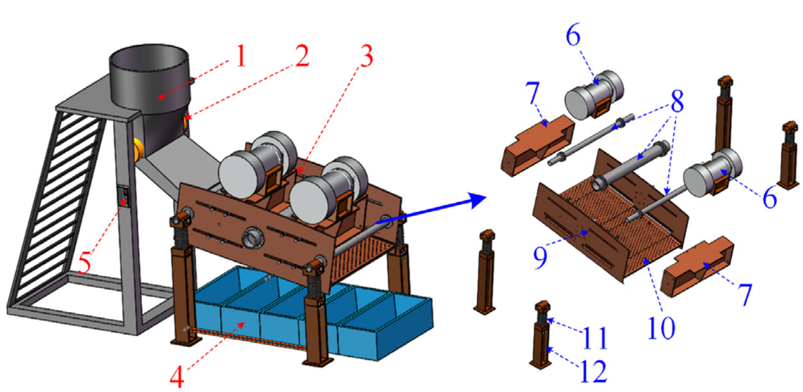


Fig. 1. Schematic diagram of the VAS system: 1. silo; 2. feeder; 3. VAS; 4. receiver; 5. frequency converter; 6. exciting motor; 7. excitation beam; 8 reinforced beam; 9. sieve box; 10. screening surface; 11. damping spring; 12. stent.