Fuel 216 (2018) 484–493

Contents lists available at ScienceDirect

Fuel

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

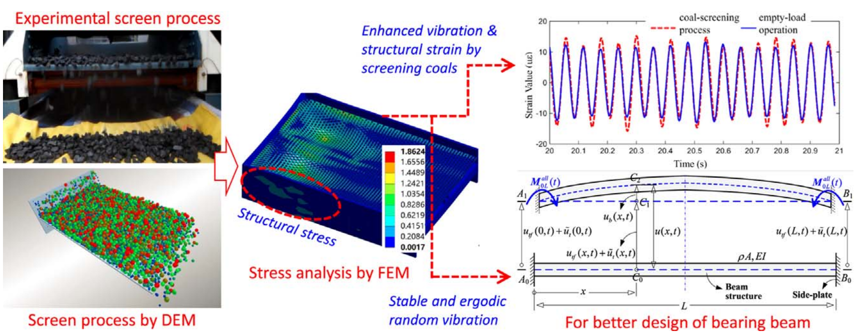
Full Length Article

Dynamic influence of screening coals on a vibrating screen

Liping Peng[a,b,c,*], Zhenqian Wang[d], Wenda Ma[a], Xihui Chen[a], Yuemin Zhao[c], Chusheng Liu[d]

[a] College of Mechanical and Electrical Engineering, Hohai University, Changzhou 213022, China
[b] State Key Laboratory of Mineral Processing, Beijing General Research Institute of Mining and Metallurgy, Beijing 102600, China
[c] School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou 221116, China
[d] School of Mechatronic Engineering, China University of Mining and Technology, Xuzhou 221116, China

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Vibrating screen
Screening process
Screening coals
Vibration
Strain

ABSTRACT

Screening is an indispensable unit operation in coal preparation. Coals often cause structural damage of a large vibrating screen during large-scale screening process. In this paper, structural vibration and strain signal of a vibrating screen were tested and analyzed for investigating the dynamic influence of screening coals on the vibrating screen. Several experiments were conducted with the empty-load operation and screening process of two different screening capacities. The obtained fundamental vibration characteristic indicated that the screening coals made the screen structure experience an enhanced vibration for the discovered additional random vibration, and the structural strain increased by 14.79% to improves the possibility of structural damage. Aiming at the emerging random vibration, a stationary test and ergodicity test were adopted for analyzing the captured vibration signal. The results demonstrated that random vibration of the vibrating screen was stable and ergodic, which means that any section of the captured signal is enough to be analyzed for representing the vibration properties of the whole screening process. Additionally, statistical characteristics of the random vibration also changed along with the screening capacity. Eventually, these new dynamic characteristics were applied into analyzing mechanics characteristic of the bearing beam theoretically and the maximum error is within 14%, while the error can reach up to 40% in a traditional calculation method without influence of screen coals considered.

1. Introduction

Coal is the main energy resource in China and provided 62% of the total energy consumption in 2016 [1]. Coal preparation is the prerequisite for clean coal utilization as well as the most cost-effective method for clean coal technology. Screening is an indispensable unit

* Corresponding author at: College of Mechanical and Electrical Engineering, Hohai University, Changzhou 213022, China.
E-mail address: plp@hhu.edu.cn (L. Peng).

https://doi.org/10.1016/j.fuel.2017.12.041
Received 30 June 2017; Received in revised form 9 November 2017; Accepted 9 December 2017

Nomenclature

A	cross-section area of the beam structure (m)
$E'_{Ru}(\tau)$	mean value of all the $R'_{uk}(\tau)$ under time delay τ
$E_{Ru}(\tau)$	mean value of all the $R_u(t, \tau)$ under time delay τ
E'_u	mean value of all the time average values
E_u	mean value of the set average function
f_s	sampling rate (Hz)
F_0	maximum excitation load (N)
K	stiffness coefficient of the damping system (N/m)
k_{sz}	stiffness coefficient of the damping system in the vertical direction (N/m)
t	actual sampling time of each subsample (sec)
$M_{0L}^{tf}(t)$	inertial bending-moment caused by FRT (N·m)
$M_{0L}^{r}(t)$	flexural bending-moment caused by BV (N·m)
$\widetilde{M}_{0L}^{t}(t)$	random bending-moment caused by ALRRT (N·m)
M	data size of each subsample
m_s	vibrating mass of the screening system (kg)
n	number of the isometric subsamples
N	$N = (N_1 + N_2)/2$
N_1	appearance time of "+"
N_2	appearance time of "−"
r	round time
$R_u(t, \tau)$	self-correlation function under the meaning of the set average
$R'_{uk}(\tau)$	self-correlation function under the meaning of the time average
T	re-sampling interval (s)
$u(t)$	set average function
u'_k	time average value
$\mathbf{u}_k$	defined k-th subsample
W_y	section modulus of the rectangular beam section
$y, \ddot{y}, \dot{y}$	displacement, acceleration and velocity of the screen structure in y-axis (m, m/s, m/s^2)

Greek letters

ω	angular speed of the exciter (rad/s)
α	vibrating direction angle (degree)
σ_k	standard deviation of each subsample
ψ	mid-value of all the standard deviations
α	significance level
τ	time delay (sec)
$\phi(x)$	shape function of the beam structure
ρ	material density of the beam structure (kg/m^3)

operation in coal preparation [2,3]. Vibrating screens are widely applied in coal preparation for the activities such as classification, dewatering, etc. [4]. With the demand for large-scale screening in coal preparation, the width of screen surface may increase up to 5 ms, which results in extremely complex dynamic characteristics of the screen structure. Generally, a vibrating screen may bear the coupled load consisting of intense excitation load initiated by the exciter, the inertial load of the screen structure and the impact load of the screening coals. These loads often induce structural damage such as beam fracture or lateral plate crack, making it difficult to meet the production requirement [5–7].

Proper mechanical design of a large vibrating screen is vital to ensure the safety, reliability and stability of the screen operation. Generally, a vibrating screen is designed based on a linear single degree of freedom (s-dof) or an uncoupled 2-dof vibration model [8,9]. Then, a linear vibration differential equation and the corresponding parameter solutions should be established to quantify the main vibration parameters such as the vibrating mass, vibrating direction angle, frequency and amplitude etc. [10–12]. Considering the s-dof vibration model, the corresponding linear vibration differential equation is $m\ddot{y} + c\dot{y} + ky = F_0 \sin\omega t$ [13], where m denotes vibrating mass of the screening system, c and k are the damping coefficient and the stiffness coefficient of the damping system, respectively, F_0 and ω are the maximum excitation load and angular speed of the exciter, respectively, y, $\ddot{y}$, $\dot{y}$ are the displacement, acceleration and velocity of the screen structure in y-axis of the set coordinate system, respectively. A traditional mechanical design based on the s-dof vibration model mainly aims at the empty-load operation, in which the designed screening capacity is not considered within the vibrating mass m, and dynamic interaction of the coals feeding-conveying-layering-through the screen surface is not counted into the load term on the right of the differential equation. Thus, the traditional vibration model is not absolutely accurate.

For the process design aspect of a vibrating screen, a virtual test can be performed instead of physical tests in order to decrease the experimental cost and improve the experimental efficiency. For example, the discrete element method (DEM) has been widely used to simulate the motion process of the particle material [14–18]. Existing simulations based on DEM mainly put particular emphasis on improving vibration screen performance by resolving the unilateral influence of the vibration parameters on the screening effect. Furthermore, the stresses applied by the flowing particles to the screen surface and the impact and abrasive wear on the screen surfaces are evaluated [19]. Finnie model was used to evaluate the wear of the screen surface and the influence of some tunable parameters including the linear vibration frequency, the excitation angle and the mesh slope were numerically studied [20]. It should be noted that the two studies mainly focus on the influence of screening materials on the screening surface. For the reason that in practice replacing the broken screening surface is common and easy while replacing or maintaining the screen structure such as the bearing beam is inconvenient and expensive, it's necessary to consider the influence of screening materials on the screen structure. For an inserve vibrating screen, the influence of the screening process can be reflected by dynamic parameters of the screen structure, thus, we will capture and evaluate the dynamic characteristics such as vibration and structure strain in this paper.

2. Experimental setup

In this study, the vibration and strain tests were performed in a CWKS1218 vibration screen. As shown in Fig. 1, CWKS1218 is a kind of eccentric-block self-synchronizing linear vibrating screen and has a single set of hyper static net-beams [5]. The vibrating direction angle (denoted by α) is 45°. The maximum excitation force (denoted by F_0) and the angular speed (denoted by ω) of the exciter is 66340 N and 32.5π rad/s (i.e. 16.25 Hz), respectively. The stiffness coefficient of the damping system in the vertical direction (denoted by k_{sz}) is 600.0 kN/m. The vibrating mass of the whole screen structure (denoted by m_s) is 1565.0 kg. Besides, the screen surface is made up of square-mesh panels, with an aperture size of 20.0 mm × 20.0 mm and a screening capacity of 15.0 ~ 30.0 t/h. According to the s-dof vibration theory, the theoretical vertical acceleration amplitude of the screen structure in the empty-load operation can be approximately calculated by the following expression [7]:

$$a_{sz} \approx \frac{F_0 \cdot \sin\alpha}{|k_{sz} - m \cdot \omega^2|} \cdot \omega^2 \tag{1}$$

Thus, the theoretical vertical acceleration amplitude of the screening structure is to be 31.12 m/s^2.

As shown in Fig. 1(a), four ICP acceleration sensors denoted by La1/