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Study on the effect of vibration parameters on the screening efficiency of the circular vibrating screen using discrete element method

Xo Van Nguyen

Faculty of Electro - Mechanics, Hanoi University of Mining and Geology, Vietnam

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ABSTRACT

A circular vibrating screen is a device for the separation of bulk materials into granules of different sizes, which is widely used in screening plants. The screening efficiency depends on various parameters, such as the vibration amplitude, vibration frequency, slope of screening surface, material properties, throwing index, etc. It is difficult to accurately assess the influence of these parameters on the screening efficiency by using conventional methods. In this work, the authors applied the Discrete Element Method (DEM) to simulate and analyze the effect of vibration parameters on the screening efficiency of circular vibrating screen. The results of the paper are graphs showing the importance of the vibration amplitude (A), the inclined angle of screening surface (α_0), the throwing index (K_v), the material properties on screening efficiency of circular vibrating screen. The findings of the study may be useful for scientists to design parameters for circular vibrating screen reliability

1. Introduction

A circular vibrating screen is a sorting machine used to split bulk materials with various kinds into different size particles thanks to rails (Guo Nian Qin et al., 2009; Zhao Yue Min et al., 2008; Chen Qing Ru, 2008). The circular vibrating screen working principle is given in Figure 1: Screen box (7) with screening surface (5) and suspended on springs (6), concentric shaft (1) mounted on the screen box through roller bearings (2), both ends of the concentric shaft with an unbalanced wheel (3) and a counterweight (4). When the machine is working, the concentric shaft rotates to create vibrating force in combination with the screening surface carrying out the sieving process to classify materials (Liu Bang Chun et al., 1989).

*Corresponding author
E-mail: nguyenvanxo@humg.edu.vn

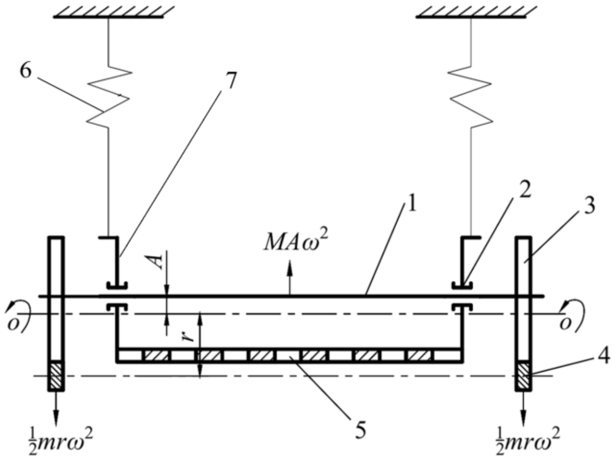

Figure 1. Operating principle of a circular vibrating screen.

1- Concentric shaft; 2- Roller bearing; 3 - Unbalanced wheel; 4 - Counterweights; 5 - Screening surface; 6 - Spring; 7 - Screen box.

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The screening efficiency alters according to working time. If the formula for static state is used to determine the screening efficiency, it is not correctly. In this study, the author has used the formula for dynamic state to calculate the screening efficiency η_{dt} (formula 1) and applied the DEM to model and analyze the effects of slope on the screening efficiency (Xo Van Nguyen et al., 2019; Xo Van Nguyen , 2013; Xo Van Nguyen , 2018; Jiang Ze Hui et al., 2009; Garcimartin A, 2002):

$$\eta_{dt} = \frac{B_t}{A_t} \quad (1)$$

Where, η_{dt} - dynamic screening efficiency at time t; A_t - the total mass of fine-grained material in the material at time t, (kg); B_t - the mass of fine-grained material becoming the product under the sieve at time t.

2. Applications of Discrete Element Method (DEM) to simulate the influence of vibration parameters on the screening efficiency of circular vibrating screens

A discrete element method (DEM), also called a distinct element method, is any of a family of numerical methods for computing the motion and effect of a large number of small particles. This method is developed in the 1970s and used in many research fields, especially in problem of discrete materials (Xu Yong et al., 2003; Zhu H P et al., 2007; Zhu H P et al., 2008). In this article, the authors utilized DEM to model the influence of vibration parameters on the screening efficiency by applying EDEM software to build the model with the following parameters (Figure 3): The size of screening surface 320mm x160 mm; the size of apertures a = 12 mm, the diameter of material particles d = (2 ÷15) mm, in which: oversize particle of hole (1≤d/a ≤1,25) is 5%; easy undersize of hole (0,2<d/a<0,7) holds a value of 80%; critical nearsize of hole (0,7≤d/a<1) contains 15%; The physical parameters of the simulation and modeling of circular vibrating screen are as shown in Table 1.

Table 1. Physical parameters of the model simulating of circular vibrating screen.

Parameter	Screening surface	Coal particle
Density (kg.m-3)	7861	1300
Shear modulus (Gpa)	79,92	1,0
Elastic coefficient	0,5	0,5
Rolling friction coefficient	0,05	0,05
Poissonratio	0,29	0,3
Static friction coefficient	0,4	0,6

To highlight the effect of each parameter on the screening efficiency, the authors perform the simulation with the following conditions: When examining the effect of any parameter, considering parameter as a variable, the remaining parameters will be taken in normal working conditions (Liu Bang Chun et al., 1989) as Table 2.

Table 2. Values of the parameters when performing the simulation.

Parameters	Value of the parameter				Condition	
A (mm)	2,3	3,0	3,7	4,4	K_v	α_o
					2,7	14
K_v	2,3	2,7	3,1	3,5	A	A_o
					3.5	14
$\alpha_o(^o)$	10	14	18	21	A	K_v
					3.5	2.7

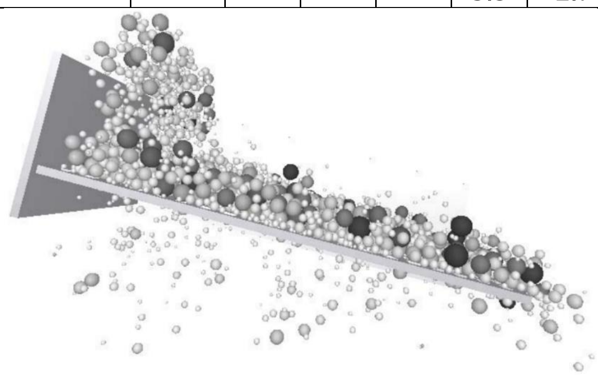

Figure 3. Material distribution model on the screening surface.

After performing the simulation, the results are as shown in Figures 4 ÷ 6:

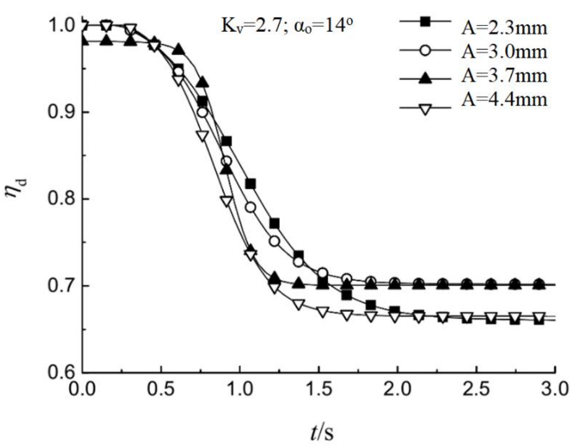

Figure 4. Effect of vibration amplitude (A) on screening efficiency.

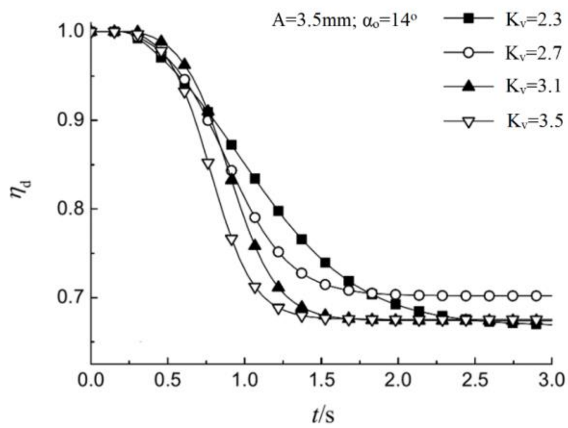

Figure 5. Effect of throwing index (K_v) on screening efficiency.

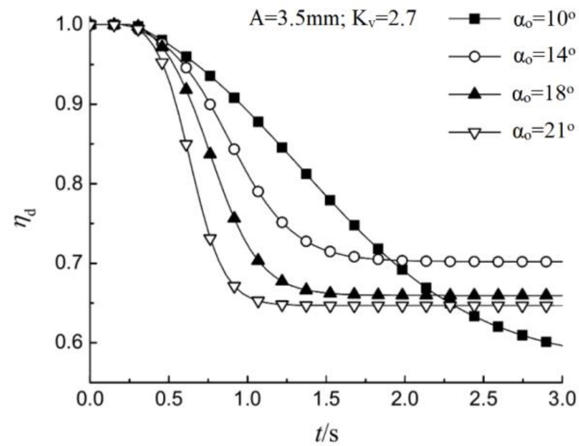

Figure 6. Effect of inclined angle of screening surface (α_o) on screening efficiency.

3. Results and discussion

As shown in Figure 4: When the vibration amplitude increases from 2,3 mm to 3,0 mm, the steady-state screening efficiency increases significantly (from 0,660 to 0,7703); When the vibration amplitude increased to 3.7 mm, the steady-state screening efficiency varied little (η_d = 0,7702); When the vibration amplitude increased to 4,4 mm, the screening efficiency decreased significantly (η_d = 0,663); This shows that: When the vibration amplitude is small, the screening efficiency will increase as the amplitude increases. But when the screening efficiency increases further, the screening efficiency will decrease. According to the simulation results for a circular vibrating screen to achieve the highest efficiency, the vibration amplitude should be in the range of 3,0 mm to 3,7 mm;

As shown in Figure 5: When the throwing index is small ($K_v = 2.3$), the screening efficiency is 0,668; When the throwing index increased ($K_v = 2.7$), the screening efficiency increased significantly and reached the maximum value of 0,773; When the throwing index continued to increase ($K_v \geq 3.1$), the screening efficiency decreased and was about 0,673; This indicates that when the throwing index is too large, the screening efficiency cannot increase, but it decreases. According to the simulation results, it is recommended to select the throwing index $K_v = 2{,}7$ to have the highest performance;

As shown in Figure 6: When the inclined angle of screening surface $\alpha_o = 10^o$, the screening efficiency is minimal; When the inclined angle of screening surface $\alpha_o = 14^o$, the screening efficiency reaches its maximum value, $\eta_d = 0.701$; When the inclined angle of screening surface increases, the screening efficiency will decrease, if the inclined angle of screening surface $\alpha_o = 21^o$, the screening efficiency is low and reaches $\eta_d = 0{,}645$.

4. Conclusion

Sieving is a relatively complicated process because, throughout the operational period, the screening efficiency of the circular vibrating screen depends on numerous parameters (such as vibration amplitude (A), throwing index (K_v), the inclined angle of screening surface (αo), properties of the material, etc.). By dint of using the discrete element method (DEM), the paper has simulated and analyzed in detail the effects of vibration parameters on the screening efficiency of the circular vibrating screen when the machine is working. As a result, the graphs show the relationship between those parameters and their influence on the screening efficiency, thereby helping the designer to select reasonably the value of oscillating parameters so that the machine works best (vibration amplitude $A = (3{,}0 \div 3{,}7)$ mm, throwing index $K_v = 2.7$ and the inclined angle of screening surface $\alpha_o = 14^o$)

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