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Vibration characteristics of an inclined flip-flow screen panel in banana flip-flow screens

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A banana flip-flow screen is an effective solution for the screening of high-viscosity, high-water and fine materials. As one of the key components, the vibration characteristics of the inclined flip-flow screen panel largely affects the screen performance and the processing capacity. In this paper, a mathematical model for the vibration characteristic of the inclined flip-flow screen panel is proposed based on Catenary theory. The reasonability of Catenary theory in analyzing the vibration characteristic of flip-flow screen panels is verified by a published experiment. Moreover, the effects of the rotation speed of exciters, the incline angle, the slack length and the characteristics of the screen on the vertical deflection, the vertical velocity and the vertical acceleration of the screen panel are investigated parametrically. The results show that the rotation speed of exciters, the incline angle, the slack length and the characteristics of the screen have significant effects on the vibrations of an inclined flip-flow screen panel, and these parameters should be optimized.

1. Introduction

Vibrating screens play an important role in modern coal processing. However, traditional horizontal screens usually encounter many problems, such as low efficiency when processing moist materials, blocking of sieve pores and so on [1–3]. Banana flip-flow screens were developed as an effective solution. Such screens integrate the advantages of both banana screens and flip-flow screens, and thus increase the efficiency and capability when processing high-viscosity, water, and fine materials [1]. In order to achieve the best screen performance, optimized design and control should be performed, which requires a fundamental understanding of the influence of geometrical and operational conditions on vibrations of the screen [4].

To date, many researchers have investigated the effect of the motion of screen surfaces on particle motions and screen performances. The particle flow of a single-deck banana screen was investigated by Liu [5] using the Discrete Element Method (DEM). Liu reported that the incline angle of the screen panel is significant for the screening performance. The effects of sieve surface gradient, vibration intensity and vibration direction angle on the screen efficiency of a banana screen were investigated by Qiao using three-dimensional DEM [6]. For a banana screen with multiple inclined screen panels, the influence of

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Nomenclature

a Parameter of the Catenary curve, m.
$\dot{a}$ and $\ddot{a}$ The first-order and second-order derivatives of parameter a with respect to time, respectively, $m \cdot s^{-1}$, $m \cdot s^{-2}$
A, B, C and D Four points on the screen panel under slack conditions
A_{ca}, B_{ca}, C_{ca} Three points on the Catenary curve
A' and B' Two ends of the screen panel under stretched conditions
A_1 and A_2 The vibration amplitude coefficients of the floating box and the outer box along the X axis, respectively, m, m.
B_1 and B_2 The vibration amplitude coefficients of the floating box and the outer box along the Y axis, respectively, m, m.
c Parameter of the Catenary curve, m.
c_{1X} and c_{2X} The equivalent damping coefficients of the connecting spring and the supporting spring along the X axis, respectively, $N \cdot s \cdot m^{-1}$
c_{1Y} and c_{2Y} The equivalent damping coefficients of the connecting spring and the supporting spring along the Y axis, respectively, $N \cdot s \cdot m^{-1}$
c_b and c_w The damping coefficients of the vibration isolation system of two-degrees-of-freedom, $N \cdot s \cdot m^{-1}$
F The exciting force generated by each eccentric block, N.
F_{c1}, F_{c2} The centrifugal forces of eccentric blocks 1 and 2, respectively, N.
F_{cx1}, F_{cx2} The components of the forces F_{c1} and F_{c2} along the x' axis, respectively, N.
F_{cy1}, F_{cy2} The components of the forces F_{c1} and F_{c2} along the y' axis, respectively, N.
F_{cx}, F_{cy} The total forces of eccentric blocks 1 and 2 along the x' and y' axes, respectively, N.
$F_X$and F_Y The exciting forces along the X and Y directions, respectively, N.
g The gravity acceleration, $m \cdot s^{-2}$
G_{ca} The gravity of the Catenary curve, N.
G_{CD} The gravity of the screen panel in the range of the arc CD, N
h Half of the distance of the left end of the screen panel relative to the x axis in the perpendicular direction, m.
$\dot{h}$ and $\ddot{h}$ The first-order and the second-order derivatives of h relative to the time, $m \cdot s^{-1}$, $m \cdot s^{-2}$
k_{1X} and k_{2X} The equivalent stiffness coefficients of the connecting spring and the supporting spring along the X axis, respectively, $N \cdot m^{-1}$
k_{1Y} and k_{2Y} The equivalent stiffness coefficients of the connecting spring and the supporting spring along the Y axis, respectively, $N \cdot m^{-1}$
k_b and k_w The stiffness coefficients of the vibration isolation system of two-degrees-of-freedom, $N \cdot m^{-1}$
l The distance of the left end of the screen panel relative to the right end of the screen panel along the x axis, m.
L The distance between the left and the right ends of the screen panel, m.
$\dot{l}$ and $\ddot{l}$ The first-order and second-order derivatives of l relative to the time, $m \cdot s^{-1}$, $m \cdot s^{-2}$
l_{CD} The length of the arc CD, m
l_s The slack length, m.
m The mass of the exciter, kg
m_0 Half the mass of the screen panel, kg
m_1 and m_2 The floating box mass and the outer box mass, respectively, kg
P The total exciting force, N.
q The ratio of rotation frequency of the exciter to the resonance frequency
r The eccentricity of the exciter, m.
s Half the length of the screen panel, m.
s_{BC} The length of arc BC, m
t Time, s.
T The tensile force at a point on the screen panel, N.
T_{ca} The tensile force at a point on the Catenary curve, N.
T_H The tensile force at the middle point of the symmetrical screen panel, N.
v_1 and v_2 Velocities of the floating box and the outer box, respectively, $m \cdot s^{-1}$
x_0 The abscissa of the right end of the screen panel in the frame $oxyz$, m
$x_1$and x_2 The abscissas of the left and the right ends of the inclined screen panel in the frame $oxyz$, m
x_c The location of the LDS relative to the left holding device in the experiment, m.
X_1 and X_2 The displacements of the floating box and the outer box along the X axis, respectively, m.
X_A and X_B The displacements of the left and the right ends of the screen panel along the X axis, respectively, m.
$\dot{X}_1$ and $\dot{X}_2$ The velocities of the floating box and the outer box along the axis, respectively, $m \cdot s^{-1}$
$\ddot{X}_1$ and $\ddot{X}_2$ The accelerations of the floating box and the outer box along the X axis, respectively, $m \cdot s^{-2}$
y The vertical defection of the screen panel in the frame $oxyz$, m