Analysis of Screening Process of Enclosed Vibrating Screen and Elastic Cantilever Sieve Composite Structure

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Abstract: Based on the enclosed vibrating screen and elastic cantilever screen as the research object, through the enclosed vibrating screen and elastic cantilever vibrating screen structure characteristics and screening process of research, for railway maintenance with a large black screen machine adopts enclosed vibrating screen and elastic cantilever screen composite structure was analysed, and the principle of screening of the cantilever screen in composite mechanism is discussed. This structure has solved the operation in the special environment, such as the slurry of the rail bed, and improved the maintenance efficiency of the railway. Meanwhile, it can be popularized and applied to other industries.

1. Introduction
With the continuous improvement of the speed in railway locomotives, the maintenance quality and maintenance speed of railway lines are also getting higher and higher. The traditional maintenance methods are difficult to adapt to the modernization requirements. At present, China's railways have increasingly adopted large-scale ballast cleaning screens. Machine completed the track bed cleaning [1]. The large ballast cleaning machine has been imported from the whole machine to its own design and manufacture. In the process of independent design, it is necessary to analyze the working principle and screening mechanism of the cleaning machine and master the basic rules of design. When the cleaning machine is working, the ballast enters the feeding port of the frame of the cleaning machine through the excavating conveyor, and enters the ballast of the vibrating screen for high speed. The impact force is large, and it works under heavy load and long-time vibration. Various forms of failures and even damages have serious consequences. At the same time, various special environments such as road bed slabs, mud squeezing and mud are encountered during the cleaning process, which has high requirements for the structure of the cleaning machine [2].

The traditional enclosed vibrating screen has the advantages of simple structure, uniform screening size, convenient maintenance and wide use. However, in the use of it, it is difficult to meet the maintenance of special railways such as road bed slabs and mud squeezing.

In recent years, the elastic cantilever vibrating screen has been promoted and used. Because its unique structure has changed the movement mode of the vibrating screen and the time of the stone, it is especially suitable for the screening of some damp, easy to be agglomeration, slab and other stone shovel, which has great superiority. The elastic cantilever screen is mainly composed of three parts: metal skeleton, damping rubber and spring steel screen [3]. The processing capacity of this vibrating screen is higher than that of ordinary vibrating screen of the same specification, especially when dealing with wet-stick stone. The elastic cantilever screens is basic not block the hole, and the effect is more obvious [4].
At present, there are few research results on the enclosed vibrating screen and the elastic cantilever screen composite structure, and there is less analysis of the motion of the upper sarcophagus migration. Therefore, it is necessary to carry out in-depth systematic research on it.

2. Enclosed vibrating screen and elastic cantilever vibrating screen composite structure

2.1. Composite vibrating screen structure

The vibrating screen uses a three-layer screen to screen the stone shovel \(^5\). The movement towards the vibrating screen is to generate a sinusoidal exciting force by a hydraulically driven vibrator, forcing the vibrating screen frame to vibrate, and sieving the sarcophagus with a three-layer screen. The points are obtained in accordance with the standard size.

The first layer of screen adopts a traditional enclosed vibrating screen structure, and the screen after installation has an angle of 22 degrees with the base. The single-piece screen structure is shown in Figure 1. The layer is used to screen the stone shovel entering the feed port of the sifter frame of the excavation conveyor. The movement towards the sarcophagus on the layer is linear, and the size is sieved. The sarcophagus larger than the mesh size of the layer discharges the vibrating screen.

The second layer of screen adopts an elastic cantilever screen structure, and the screen is as shown in Fig2.

The second layers of sievescreenethefirstlayer of sieved stone shovels. The elastic cantilever screen is parallel to the first layer of screens and has an angle of 22 degrees with the base of the cleaning machine. The sarcophagus is in the layer. The movement is more complicated. On the one hand, the gravel moves under the action of the vibrating screen for the elastic cantilever screen, and the elastic cantilever screen produces high-frequency secondary vibration, which is the movement towards the gravel along the direction perpendicular to the screening plane.

The third layer screen has the same structure as the first layer and adopts a conventional enclosed vibrating screen structure. The screen aperture size becomes smaller, and the stone raft smaller than the standard size is discharged from the vibrating screen.

2.2. Composite vibrating screen characteristics

The traditional enclosed vibrating screen has the advantages of simple structure, accurate screening size and long life of the screen, and has been widely used in many industries.

However, the traditional enclosed screen structure has many shortcomings:

(1) The traditional enclosed screen has a small inclination angle. The small inclination angle of the sieve screen will cause the movement of the gravel to be inconvenient, and the small particle gravel is not easy to move down to contact the mesh surface;

(2) It is easy to cause gravel accumulation. When the conventional enclosed screen is screened, it is easy to accumulate the gravel caused by the excessive thickness of the gravel layer, thereby increasing the load of the vibrating screen and reducing the vibration intensity;

(3) A jam appears. The traditional enclosed screen mesh has a fixed size, and the gravel with a size slightly larger than the mesh hole is not easily thrown to cause jam, which reduces the screening efficiency \(^6\).
The structure of the cantilever screen is different from the traditional screen structure. The cantilever screen is free at one end and the adjacent cantilever is not constrained by the horizontal bar, so it has many advantages [6]:

1. Improve the service life of the screen. The sarcophagus on the cantilever screen is carried by the cantilever. When sieving, the direction of movement of the sarcophagus is the same as that of the cantilever sifter, thereby reducing the wear rate of the sifter and providing the service life of the slat.

2. Improve the screening ability. The cantilever screen mesh hole has an elongated shape with an open end, and the stone slag particle jam can be discharged from the open end of the sieve hole by squeezing through other gravel when sieving, thereby improving the screening ability.

3. Secondary vibration improves the screening quality. When the cantilever screen is screened, in addition to the screen box vibration, the cantilever screen can generate secondary vibration. Through the secondary vibration of the cantilever, the gravel particles are loosened, and it is easier to enter the next layer without blocking the hole, thereby improving the screening quality.

The cantilever screen of the cantilever screen structure is free at one end, and the adjacent cantilever is not restrained by the horizontal bar, so that the flexible vibration can be fully released. Compared with the traditional enclosed screen structure, the cantilever screen structure can eliminate the screen closing pit and reduce the jam caused by the gravel, thereby improving the screening efficiency and the screening quality.

3. Analysis of screening mechanism of elastic cantilever sieve

3.1 Elastic cantilever screen structure

The structure of the cantilever mesh screen is shown at Figure 2 and Figure 3.

The structure of the single row cantilever mesh screen is equidistantly arranged by cantilever sieve strips of the same specification, such that one end is fixed to the beam and the other end is suspended (Fig. 2). The structure of the combined cantilever mesh screen is composed of a single row of cantilever mesh screens with a beam head and a free end as a tail, which are arranged in a stepped and overlapping arrangement. The gravel enters from the upper end of the upper layer of the cantilever mesh and flows out from the lower end of the lower layer [7].

3.2 Screening mechanism of elastic cantilever screen

Figure 3 is a schematic view showing the structure of a single cantilever strip of an elastic cantilever screen. The secondary vibration of the cantilever screen is based on the lateral vibration of the cantilever beam. In order to make the calculation simple, the calculation is carried out under the condition that the vibrating screen is unloaded.

Established as the ground coordinate system, which is the coordinate system fixed on the screen box. The relationship between the deflection formula, bending moment and external force of the joint beam transverse vibration differential equation for flexible cantilever strips [8]:

\[ EI \frac{\partial^4 y'}{\partial x^4} = -\rho \frac{\partial^2 y'}{\partial t^2} \]

(1)

The \( \rho \) is the linear density of the cantilever strip.

Relationship between two coordinate systems

\[ x' = x + x_0 \]
\[ y' = x + A \sin \omega t \]

(2)

The vibration equation of the single cantilever strip in the ground coordinate system is

\[ EI \frac{\partial^4 y}{\partial x^4} = -\rho \frac{\partial^2 y}{\partial t^2} + \rho A \omega^2 \sin \omega t \]

(3)

The solution is equivalent to the solution of the fixed-end cantilever beam over its entire length plus the set of alternating stresses. The shape function is

\[ X_i(x) = c h \beta_i x - \cos \beta_i x + \xi_i (s h \beta_i x - \sin \beta_i x) \]

(4)
The eigenvalue of the vibration equation is given by \[\xi_i = -\frac{ch\lambda_i + \cos \lambda_i}{sh\lambda_i + \sin \lambda_i}\] (5).

Equation solution

\[y(x,t) = \sum X_i(x)q_i(t)\] (6)

The generalized mass relative to the generalized coordinates is

\[M_i = \int_{0}^{l} d(x) X_i^2(x) dx\] (7)

Then available

\[M_i = \int_{0}^{l} d(x) [ch\beta_i x - \cos \beta_i + \xi_i (sh\beta_i x - \sin \beta_i x)]^2 dx\]

\[M_i = \frac{d}{\beta_i} \int_{0}^{\beta_i} [chx - \cos x + \xi_i (shx - \sin x)]^2 dx\] (8)

Make

\[S_i = \int_{0}^{\beta_i} [chx - \cos x + \xi_i (shx - \sin x)]^2 dx\] (9)

So there is \(M_i = dS_i/\beta_i\)

Generalized force

\[Q_i = \frac{1}{M_i} \int_{0}^{l} p(x,t)X_i(x) dx\] (10)

because,

\[p(x,t) = dA\omega^2 \sin \omega t\] (11)

Therefore,

\[Q_i = \frac{1}{M_i} \int_{0}^{l} dA\omega^2 \sin \omega t [ch\beta_i x - \cos \beta_i x + \xi_i (sh\beta_i x - \sin \beta_i x)] dx\] (12)

\[Q_i = \frac{dA\omega^2 \sin \omega t}{M_i \beta_i} \int_{0}^{\beta_i} [chx - \cos x + \xi_i (shx - \sin x)] dx\] (13)

Assume

\[S_i' = \int_{0}^{\beta_i} [chx - \cos x + \xi_i (shx - \sin x)] dx\] (14)

Then available,

\[Q_i = \frac{A\omega^2 \sin \omega t S_i'}{S_i}\] (15)

The generalized coordinate differential equation is

\[\ddot{q}_i + p_i^2 q_i = Q_i\] (16)

\[\ddot{q}_i + p_i q_i = \frac{A\omega^2 \sin \omega t S_i'}{S_i}\] (17)

Corresponding to the solution of forced vibration

\[q_i = \frac{A\omega^2 S_i'}{S_i (p_i^2 - \omega^2)} \sin \omega t\] (18)
\[ p_i = \beta_i^2 \sqrt{\frac{EI}{d}} \]  

(19)

Analyses the solution for this equation and get

\[ y(x,t) = \sum_i \left[ \left( ch \beta_i x - \cos \beta_i x + \xi_i \left( sh \beta_i x - \sin \beta_i x \right) \right) \frac{A \omega^2 S_i}{S} \sin \omega t \right] \sin \omega t \left( \frac{\lambda_i^2 \sqrt{\frac{EI}{d}}}{\ell^2} - \omega^2 \right) \]  

(20)

Where \( \lambda_i \) is the eigenvalue of the vibration equation and is derived from the equation \( \cos \lambda_i ch \lambda = -1 \); \( \beta_i \) is the natural frequency of the sieve. The solution on the ground coordinate system is

\[ y'(x,t) = y(x,t) + A \sin \omega t \]  

(21)

In actual production, the material of the cantilever sieve strip is steel, and the elastic modulus E is about 200 GPa. In the calculation, since the E value is large, and the high-order amplitude is small compared with the first-order amplitude, it can be neglected, and the approximate solution of the vibration equation can be \( i=1 \).

When the geometric parameters of the adjacent sieve bars or the mechanical parameters are different, the secondary vibration of the sieve bars will be different, and dynamic concavities and convexities appear on the entire surface of the sieve.

In actual production, the diameter of the screen is 16mm, the length is 450mm, the spacing is 15.5mm, the motor speed is 840r/min, and the first-order approximate solution of the secondary vibration of the screen is

\[ X(x) = ch4.1668x - \cos 4.1668x - 0.7341(sh4.1668x - \sin 4.1668x) \]

\[ q(t) = -0.0414A \sin 28\pi t \]

\[ y(x,t) = X(x)q(t) \]  

(22)

The amplitude of the vibrating screen chamber is about 5 mm, and the amplitude of the end of the screen is 0.204 A. Estimate the change in the mesh hole to

\[ \delta \leq \sqrt{15.5^2 + (4 \times 0.204)^2} - 15.5 \]  

(23)

It can be seen from the calculation results that the secondary vibration has little effect on the change of the mesh size. However, in the case where the diameters of the two sieve bars are different, the spacing of the sieve bars will change at a frequency of 14 Hz. In the case of such high-frequency interlaced vibration, the particles blocked in the sieve holes are loosened, and the plugging is reduced.

4. Conclusions
By analysing the characteristics of the traditional closed vibrating screen and elastic cantilever screen structure, a closed-type vibration and elastic cantilever composite screen structure of a large-scale cleaning machine of a railway was studied, and the following conclusions were drawn:

(1) The use of composite structure screen can ensure the dimensional accuracy of the sieved sarcophagus, and can greatly improve the screening efficiency.

(2) The high frequency secondary vibration of the cantilever sieve strip helps to eject the stone particles in the sieve hole and increase the screening rate. It has a good effect on the screening of special stone shovel such as slab knot, mud smashing mud.

(3) The high-frequency secondary vibration of the cantilever sieve is related to the diameter and length of the cantilever sieve.
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