Vibrating Screen without Vibration being transmitted to Supporting Structure

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At present, both at home and abroad, vibrations are to be transmitted to the supporting structures by vibrating screens, which is harmful to the health of operating personnel. For conventional screen constructions the resulting dynamic load could not be avoided. But the author developed a new construction, the theoretical analysis of which showed that practically no vibration transmission to supporting structures is possible. Although those ideal conditions could never be met in practice, the actual vibration which is to be transmitted was reduced by (78.6-90)%. It is of great importance for the construction of large vibrating screens. The author wishes to thank most sincerely Professor Ren Deshu, technical consultant of Beijing Metallurgical Equipments Institute, for his valuable and helpful suggestions and comments.

1. Preamble

Circular path vibrating screens are widely used in metallurgical, mining and building industries etc. Although they have numerous advantages such as simple construction, reliable operation, high production and low power consumption, the vibration as transmitted to supporting structures are nevertheless harmful to operating personnel. For instance, the vertical dynamic vibration of heavy vibrating screens Types H-1736, 2H-1735 and 2H-2460 are ±640, ±500 and ±1800 kgf respectively. The frequency of vibrating screens are as high as 1000-1450 cycles/min. Therefore, how to reduce dynamic load for vibrating screens are problems mostly concerned.

2. Working Principle of New Vibrating Screens and Their Theoretical Analysis

The new vibrating screens consist of two vibrators, which are connected through a polyurethane toothed belt to assure synchronous running. The bearings are supported through spring-rope to supporting structures, as shown in Fig. 1.

The working principle of new vibrating screen is shown in Fig. 2.

Let $M_1$ be the mass of left-half of screen frame and related on-screen material
$m_1$ be the mass of eccentric weight left-half for of screen frame
$M_2$ be the mass of right-half of screen frame and related on-screen material
$m_2$ be the mass of eccentric weight for right-half of screen frame
$R_1$ be the distance between $M_1$ and suspension center
$R_2$ be the distance between $M_2$ and suspension center
$r_1$ be the distance between eccentric weight $m_1$ and suspension center

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Let \( r_2 \) be the distance between eccentric weight \( m_2 \) and suspension center.

From the equilibrium of torques:

\[
\begin{align*}
  m_1gr_1 & - M_1gR_1 = (m_1 + M_1)g\Delta r_1 \\
  m_1r_1 & - M_1R_1 = (m_1 + M_1)\Delta r_1
\end{align*}
\]

Thus

\[
\Delta r_1 = \frac{m_1r_1 - M_1R_1}{m_1 + M_1}
\]

Wherein \( g \) is the gravity acceleration.
If $m_1r_1-M_1R_1>0$, then $\Delta r_1>0$, representing that the mass center of left-half of screen frame (with related on-screen material) and eccentric weight lies somewhere between suspension center and eccentric mass.

If $m_1r_1-M_1R_1<0$, then $\Delta r_1<0$, representing that the mass center of left-half of screen frame (with related on-screen material) and eccentric weight lies somewhere between suspension center and $M_1$.

If $m_1r_1-M_1R_1=0$, then $\Delta r_1=0$, representing the mass center of left-half lies on the suspension center.

Similarly,

$$\Delta r_2 = \frac{m_2r_2-M_2R_2}{m_2+M_2}$$

Wherein $\Delta r_1$ and $\Delta r_2$ represent the distance between mass center of left-half and right-half frame (with related on-screen material) to their respective suspension centers.

To analyze the underlying working principle, let us resolve spring coefficient of the supporting springs into vertical and horizontal components, as illustrated in the working sketch in Fig. 3. The damping (air resistance, internal friction of suspension spring etc.) is so small that it could be neglected.

From D'Alembert principle.

$$\begin{cases}
M \frac{d^2x}{dt^2} + C_x x - M \left( \frac{m_1r_1-M_1R_1}{m_1+M_1} \right) \omega^2 \cos \omega t = 0 \\
M \frac{d^2y}{dt^2} + C_y y - M \left( \frac{m_1r_1-M_1R_1}{m_1+M_1} \right) \omega^2 \sin \omega t = 0 \\
\frac{d^2x}{dt^2} + \frac{C_x x}{M} = \left( \frac{m_1r_1-M_1R_1}{m_1+M_1} \right) \omega^2 \cos \omega t \\
\frac{d^2y}{dt^2} + \frac{C_y y}{M} = \left( \frac{m_1r_1-M_1R_1}{m_1+M_1} \right) \omega^2 \sin \omega t
\end{cases}$$

wherein $M$- total mass of left-half of frame (with related on-screen material), $M=m_1+M_1$

$x$- the displacement along $x$-axis of the mass center of $M$

$y$- the displacement along $y$-axis of the mass center of $M$

![Fig. 3.](image-url)
Vibrating Screen without Vibration being transmitted to Supporting Structure

\( c_x \) - spring coefficient along \( x \)-axis
\( c_y \) - spring coefficient along \( y \)-axis
\( \omega \) - angular velocity of vibrations
\( t \) - time

Let
\[
\frac{C_x}{M} = K_x \omega^2
\]
\[
\frac{C_y}{M} = K_y \omega^2
\]
\[
\left( \frac{m_1 r_1 - M_1 R_1}{m_1 + M_1} \right) \omega^2 = h
\]
Thus
\[
\begin{cases}
\frac{d^2 x}{dt^2} + K_x \omega^2 x = h \cos \omega t \\
\frac{d^2 y}{dt^2} + K_y \omega^2 y = h \sin \omega t
\end{cases}
\]

The complete solution of differential equations consist of a general solution for free vibration and a particular solution for forced vibration. The amplitude of free vibration gradually disappears (although damping is very small), while the amplitude of forced vibration remains stable. We learned from practice that only the stable forced vibration need be taken into consideration with the following particular solution:

\[
\begin{align*}
x &= \left( \frac{h}{K_x \omega^2 - \omega^2} \right) \cos \omega t \\
y &= \left( \frac{h}{K_y \omega^2 - \omega^2} \right) \sin \omega t \\
x &= \left( \frac{m_1 r_1 - M_1 R_1}{m_1 + M_1} \right) \frac{\omega^2}{K_x \omega^2 - \omega^2} \cos \omega t \\
y &= \left( \frac{m_1 r_1 - M_1 R_1}{m_1 + M_1} \right) \frac{\omega^2}{K_y \omega^2 - \omega^2} \sin \omega t
\end{align*}
\]

It is technically feasible to choose suitable mass of eccentric weights so that the mass center of the left-half lies just on suspension center \( (m_1 r_1 - M_1 R_1 = 0) \), then
\[
\begin{align*}
x &= 0 \\
y &= 0
\end{align*}
\]

Similarly, we can choose eccentric weights of the right-half so that \( m_2 r_2 - M_2 R_2 = 0 \) and the mass center of the right-half lies on the suspension center.

We now come to the conclusion that theoretically it is possible that the vibration transmitted by the vibrating screen to supporting structure can be eliminated. Owing to numerous factors as errors in manufacturing and adjustment, a small amount of vibration will be transmitted finally to supporting structures. In the latter case,

\[ \Delta r_1 = \frac{m_1 r_1 - M_1 R_1}{m_1 + M_1} \] is very small. (the mass center of the left-half total mass deviates from the suspension center)

\[
\begin{align*}
x &= \Delta r_1 \left( \frac{\omega^2}{K_x \omega^2 - \omega^2} \right) \cos \omega t \\
y &= \Delta r_1 \left( \frac{\omega^2}{K_y \omega^2 - \omega^2} \right) \sin \omega t
\end{align*}
\]
a. If

\[ K_x = K_y = K \]

\[ x = \Delta r_1 \left( \frac{\omega^2}{K^2 - \omega^2} \right) \cos \omega t = A_x \cos \omega t \]

\[ y = \Delta r_1 \left( \frac{\omega^2}{K^2 - \omega^2} \right) \sin \omega t = A_y \sin \omega t \]

\[ A_x = A_y = \Delta r_1 \frac{\omega^2}{K^2 - \omega^2} \]

The longest displacement along \( x \)- and \( y \)-axis of mass \( M \) are equal, the path of \( M \) become a circle.

b. If

\[ K_x \neq K_y \]

\[ x = \Delta r_1 \frac{\omega^2}{K^2 - \omega^2} \cos \omega t = A_x \cos \omega t \]

\[ y = \Delta r_1 \frac{\omega^2}{K^2 - \omega^2} \sin \omega t = A_y \sin \omega t \]

\[ A_x \neq A_y \]

The longest displacements along \( x \)- and \( y \)-axis of mass \( M \) are not equal, the path is an ellipse.

Even the mass of screen frame with related on-screen material in the left-half and those in the right-half and their eccentricity vibrator are unequal, we can adjust them so that the mass center lie on their respective suspension centers and the vibration transmitted to supporting structure could be reduced to zero and the movement of screen be made a true plane circular path. But the movements of two vibrators must be synchronous which are assured by toothed-belt. If not synchronous, the movement of screen will be an irregular one.

3. Test with new and old screen and their comparisons

During the test of new screen, \( V \)-type transmission belt for connecting the vibrators driving was first tried but the slip could not be avoided. Then chain drive was tested. The drive is satisfactory and slip is eliminated, but it causes a heavy noise when circumferential speed attains 10 m/s. It also needs constant lubrication and is exposed to wear. The author then tried a polyurethane toothed-belt as used in Shanghai No. 8 Woolen Textile Factory, which is imported from EEC countries. It gives excellent results and the synchronous running of two vibrators are thus assured.

Finally, it was decided to use polyurethane synchronous toothed-belt. They don’t need lubrication, are wear-resistant and lasting.

The test screen is of double-deck type and has the following characteristics:

<p>| | |</p>
<table>
<thead>
<tr>
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<th></th>
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<tbody>
<tr>
<td>Area of screen</td>
<td>500 × 1000 mm</td>
</tr>
<tr>
<td>Frequency</td>
<td>1100 cpm</td>
</tr>
<tr>
<td>Double amplitude</td>
<td>6 mm</td>
</tr>
</tbody>
</table>

During the test of convention screen, the tester holds a wooden stick in the hand and let its other end against the suspension device (Fig. 5). The amplitude is rather large and the hand gets a violent vibration feeling. But if one touches the corresponding suspension device on the new screen, the feeling is very slight. Then a micrometer was attached on the top of suspension in Fig. 4 and 5 and four points are measured respectively.

The average values of four testing points are as follows:
As the spring coefficients are the same, the transmitted vibrations for new screen have reduced by \( \frac{6.1 - 1.3}{6.1} = 78.6\% \) (at 1100 cpm). The reduction rate of vibration transmission at 750 cpm is \( \frac{6.0 - 0.575}{6.0} = 90\% \), i.e., the transmitted vibration for new screen is only 10\% of that of old ones.

When load (i.e., on-screen material) fluctuates \( \pm 30\% \), the fluctuation of transmitted vibration will not be larger than 13\%.

**References**

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