Computational Analysis on Material Movement of LS Screw Conveyor

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Abstract. In industrial production, LS screw conveyors are widely used due to their high transmission efficiency and simple operation. In this paper, the material movement influence such as the helix angle, the friction angle, and the resultant force of LS conveyor is studied, and the improved design of the blade is carried out to make its perform better in production.

1. Introduction

Screw conveyors [1] are used in a wide range of applications and are commonly used in industrial production. They are mainly used for conveying horizontal or inclined powders, granules and small pieces of materials such as coal, grain, dust and so on. The temperature of the object to be transported should generally be below 200 degrees. However, it is not suitable for transporting objects that are prone to deterioration [2], easy to stick, or easy to form a block. Its main use is generally in concrete mixing stations where its role is maximally utilized. To solve the problem, the material movement should be analyzed.

2. Computational Analysis of Material Movement

Assume $\alpha$ is the helix angle, which indicates the helix is in a straight line. The force on the material of the helicoid at $r$ is $P_n$. The angle between frictional force $P_n$ and helix deviation is $\phi$. For the $P_r$ and $P_t$, they are the components of this resultant force. The determinants of the $\phi$ angle are divided into two parts, one is the friction angle $\rho$, and the other is the roughness. A spiral surface that is usually stamped or machined, ignoring the influence of roughness, then $\phi \approx \rho$.

The material will make a reciprocating motion inside the trough [3], because its speed can be divided into two parts, one is the speed of the circumference, and the other is the speed of movement along the axis. The two speeds can be merged into a combined speed[4].

Assuming the speed is $n$, the material movement speed can be obtained:

$$v_n \cos \rho = l_{AB} \sin \alpha$$  \hspace{1cm} (1)

$$l_{AB} = \frac{2\pi rn}{60}$$  \hspace{1cm} (2)

Therefore,

$$v_n = \frac{2\pi rn}{60} \times \frac{\sin \alpha}{\cos \rho}$$  \hspace{1cm} (3)

The circumferential velocity is:
\[ v_r = v_n \sin(\alpha + \rho) = \frac{2\pi rn}{60} \times \frac{\sin \alpha \sin(\alpha + \rho)}{\cos \rho} \] (4)

Therefore, \( \mu = \tan \rho \) is placed in the equation, and the speed of the circumference can be found as:

\[ v_r = \frac{2\pi rn}{60} \times \sin \alpha (\sin \alpha + \mu \cos \alpha) \] (5)

Because,

\[ \tan \alpha = \frac{s}{2\pi r} \] (6)

\[ \sin \alpha = \frac{s}{\sqrt{1 + \left(\frac{s}{2\pi r}\right)^2}} \] (7)

\[ \cos \alpha = \frac{\frac{s}{2\pi r}}{\sqrt{1 + \left(\frac{s}{2\pi r}\right)^2}} \] (8)

Therefore, by substituting the above formulas, the formula of the circumferential velocity of the material particles is obtained:

\[ v_r = \frac{sn}{60} \times \frac{s}{2\pi r} + \mu \left(\frac{s}{2\pi r}\right)^2 + 1 \] (9)

In the above, \( s \) is the pitch on screw; \( n \) is the rotational speed on screw, \( r \) is the material’s axis radius, \( \mu \) is the friction coefficient, and \( \mu = \tan \rho \).

Deriving \( r \), the radius at which the maximum value of the \( v \) circle is present:

\[ r_{\text{max}} = \frac{\mu + \sqrt{1 + \mu^2}}{2\pi} \] (10)

At the same way, according to the velocity decomposition of Figure 1, the axial transport speed formula of the material particles can be obtained:

\[ v_A = \frac{sn}{60} \times \frac{1 - \mu}{\left(\frac{s}{2\pi r}\right)^2 - 1} \] (11)

When the horizontal screw conveyor is produced, a phenomenon occurs at the bottom of the tank. That is, the material to be transported will be biased to one side, and both the deflected surface and the horizontal plane will produce an angle \( \phi \). The definition is the collapse angle, from Figure 1, at this time the material will reach an equilibrium state, when \( \phi > \phi_d \), the placed material will produce a downward sliding trend, and this phenomenon is called collapsed state. The collapsed material produces something called stream. When the conveyor is running, the material surface angle is less than or equal to the collapse angle.

\[ \phi < \phi_d = 0.7\phi_0 \] (12)

In the above, \( \phi_0 \) is the friction angle when the material is stationary; \( \phi_d \) is the collapse angle of the material surface when the conveyor is working; \( \phi \) is the corner of the material surface.
3. **Blade Design**

In the working state of the conveyor, the filling factor of the material in the tank can affect the conveying process and the energy consumption. Generally, the filling factor is $\psi < 45\%$. From Figure 2, it can be obtained that the force of the material through the spiral surface in the axial direction is:

$$p_A = p_n \cos(\alpha + \beta)$$  \hspace{1cm} (13)

To make the $p_A > 0$, then:

$$\alpha < \frac{\pi}{2} - \rho$$  \hspace{1cm} (14)

The maximum allowable pitch value is obtained by the following formula:

$$s_{\text{max}} \leq \pi d \tan\left(\frac{\pi}{2} - \rho\right)$$  \hspace{1cm} (15)

$$s_{\text{max}} \leq \frac{\pi d}{\mu}$$  \hspace{1cm} (16)

If $k_1 = d/D$ is substituted, then

$$s_{\text{max}} \leq \frac{\pi k_1 D}{\mu}$$  \hspace{1cm} (17)

As shown in Figure 1, for the velocity component, it is affected by the size of the pitch. The axial velocity will change with the pitch. As the pitch becomes larger, it will also change, and the speed of the circle becomes an inappropriate distribution. When the circle of the spiral circumference is $v_r \leq v_A$, it is calculated by the formula:

$$\frac{sn}{60} \times \frac{s + \mu}{(2\pi r)^2 + 1} \leq \frac{sn}{60} \times \frac{1 - \mu \frac{s}{2\pi r}}{(2\pi r)^2 + 1}$$  \hspace{1cm} (18)

$$s \leq 2\pi r \frac{1 - \mu}{1 + \mu} = \tan\left(\frac{\pi}{4} - \rho\right) 2\pi r$$  \hspace{1cm} (19)

Because $2r = D$, the next condition of the pitch is:

$$s \leq \tan\left(\frac{\pi}{4} - \rho\right) \pi D$$  \hspace{1cm} (20)
Figure 2 is a correlation of the volumetric productivity and the coaxial diameter of the horizontal screw conveyor. As can be seen from Figure 2, the volumetric productivity of the horizontal screw conveyor varies with the volumetric productivity and the coaxial diameter. Figure 3 shows the ratio of the speed of manufacture of the conveyor volume to the s/D ratio, as well as the associated material and coefficient of friction. As can be seen from Figure 3, the s/D limit is 0.8-1.25. Outside this range, the productivity will decrease. The material and friction coefficient are related to the yield. When the s/D ratio is a little large, following the change of \( f_1 = \tan \phi_1 \), the production has fallen very quickly.

![Figure 2. The relationship between volumetric productivity of screw conveyor and diameter of shaft](image1)

![Figure 3. The relationship between volumetric productivity and ratio of screw conveyor](image2)

The maximum allowable speed of the helix is calculated as follows:

\[
n_{\text{max}} = \frac{A}{\sqrt{D}}
\]

(21)

In the above, D is the spiral diameter; A is the material property coefficient.

4. Conclusion

This paper discusses the material movement of the LS Screw conveyor and optimizes the conveyor blade parameters. The study result shows the proper selection of the material and the smoothness of the spiral blade is vital for the productivity of LS screw conveyors. Therefore, it is also necessary to take proper material and smoothness of the spiral blade to reduce the coefficient of friction between the material and the blade.
5. References

[1] Waje S S, Thorat B N, Mujumdar A S. Screw Conveyor Dryer: Process and Equipment Design[J]. Drying Technology, 2007, 25(1):241-247.

[2] Bedogni V, Manes A. An experimental investigation of the effect of the placement angle on the collapse of ice screw anchors[J]. Engineering Failure Analysis, 2012, 26(12):139-150.

[3] Ariff T F, Jusoh M F B, Parnin M, et al. Improving Efficiency and Enhancing Productivity in Transporting Fertilizers by Using Conveyor Belt Cleaners[J]. Advanced Materials Research, 2014, 1082:505-510.

[4] Wang X, Fan X B, Liu H X. Research on Cold Taper-Rolling Law of the Spiral Blade Based on Finite Element Method[J]. Materials Science Forum, 2008, 575-578:305-310.