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Improve wear resistance and stability of conveyor screws in the iodized salt mixing line in Vietnam

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ABSTRACT: The screw conveyor is a type of continuous conveying machine, without traction parts. Mainly for transporting and mixing granular and solid materials. Transporting materials with screw conveyors has many advantages: Materials move in a closed box, receive and unload at any location, so there is no loss or spillage, and it is safe. This type is best used for hot and toxic materials. Simple structure, cheap, can be both transported and mixed. Small installation area.

However, there are also disadvantages: Because there is a gap between the trough and the screw blade, it is easy to crush part of the material. Because there is large friction and mainly sliding friction, the spiral blades and troughs wear out quickly. It is also for this reason that the energy loss is large and cannot be used for highly sticky materials. In the case of using a screw conveyor in an iodized salt mixing line in Vietnam, the corrosive nature of salt will reduce the life of the screw conveyor.

This study will calculate, design and manufacture screw conveyors regarding 2 issues:

- Research on motivation and dynamics. Find technological solutions to improve the abrasion resistance of screw blades in an iodized salt environment.
- Research and calculate stability, propose design, manufacturing and assembly options to improve the stability of screw conveyors.

KEYWORDS: Screw conveyor; Dynamics and dynamics of screw conveyors; Stable for screw conveyors; Anti-wear for screw conveyors.

I. INTRODUCTION

Screw conveyors are widely used in agriculture and process industries, primarily for lifting or transporting large quantities of materials over short to medium distances [4], [7]. They are especially effective when transporting granular solids. Screw conveyor designs tend to be based on experience, mainly stopping at the simple design and manufacturing level. Specifically, calculate durability and hardness. Considered the screw conveyor performance when working under the influence of its environment under the following conditions: screw rotation speed [1], screw conveyor tilts [2], and its volume filling capacity [3]. However, when designing, only preliminary calculations are made [2], [5], [6], then the table does not take into account age, durability, torque, horizontal - axial bending; The abrasion resistance and stability of the screw conveyor has not been considered, so it affects the life of the product, reducing production efficiency and investment.

In this study, we are especially interested in the following three issues:

1. Abrasion resistance of:

+ Electrochemical corrosion between iodized salt material and screw conveyor blade surface material.

+ Friction between the iodized salt material flow and the screw conveyor barrel material.

2. Calculate durability test.
3. Calculate screw conveyor stability

Based on the analysis to clarify the mechanism and main causes of wear, from there, propose solutions to find ways to overcome: material selection; create mechanical properties of surface material layer; lubrication (or surface coating); Choose the rotation speed and ensure the system's rigidity...

II. KINEMATIC, DYNAMIC OF MATERIAL TRANSPORT PROCESS BY SCREW TRANSPORT

2-1-Load acting on the conveyor screw

To demonstrate the load acting on the screw conveyor, we consider the operation of a two-bearing screw conveyor with a constant helical

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pitch. The capacity of the screw conveyor and the pressing pressure of the material are known. It is assumed that the pressure distribution along screw length can be considered to change according to the law of increasing steadily from 0 to working pressure.

We have the following symbols:

p_{max} - maximum normal pressure on screw surface
p_N - normal pressure varies with screw shaft length
p_x - shaft pressure
p_r - pressure perpendicular to the radius, opposite to the direction of rotation
p_y- component pressure along the y axis
p_z- component pressure along the z axis
q - intensity of continuous load
β- elevation angle of screw line
R_2- inner radius of the screw
R_1- external sell of the screw
t - pitch of screw conveyor
n - number of rotations of the screw in one minute
M_x - torque
m_x- magnitude of continuous torque
m_y - the magnitude of the continuous moment about the y axis
m_z- the magnitude of the continuous moment about the z axis
M_u- bending moment
L - screw length
N_x- axial force
Q_y- horizontal force acting in the yx plane
Q_z -horizontal force acting in the zx plane
m - number of screw twists

Figure 2.1 shows a diagram for calculating the change in normal pressure along the length of the conveyor screw, which means accepting that the pressure changes according to a linear law along the entire length.

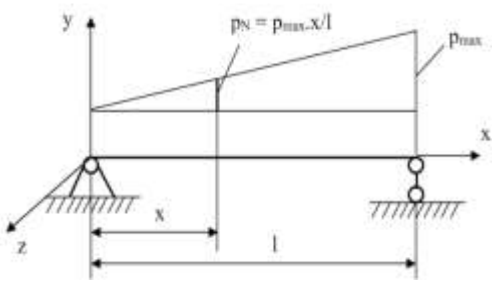

Figure 2.1. Diagram for calculating the change in normal pressure according to the screw length

The pressure p_N acting perpendicular to the screw surface can, as well as the screw path, be divided into p_x and p_r components:

shaft pressure:

$p_x = p_N.\cos\beta$ (2.22)

pressure perpendicular to the radius:

$p_r = p_N.\sin\beta$ (2.23)

trong đó :β là góc nâng trung bình của đường vít

Trên bề mặt của vít tải, ta tách ra một phân tố diện tích vô cùng nhỏ dF

$$dF = r.d\alpha.dr\frac{1}{\cos\beta} \quad (2.24)$$

It is necessary to divide bycosβ, because the quantityr.dα.dris the projection of the screw surface on a plane perpendicular to the screw axis.

Within the limits of angledα, the force is axial:

$$dN_x = d\alpha\int_{R_2}^{R_1} p_N.\cos\beta.r.dr\frac{1}{\cos\beta} \quad (2.25)$$

The pressure along the radius can be considered constant, therefore:

$$dN_x = p_N\frac{R_1^2 - R_2^2}{2}d\alpha \quad (2.26)$$

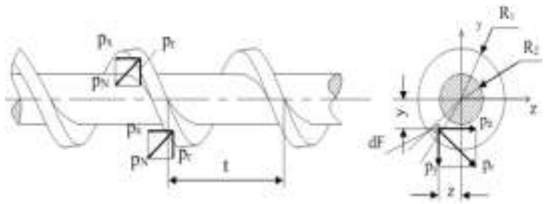

Figure 2.2. Load acting on the conveyor screw

In the case of movement of points along the screw path, the displacement of an angle equal to2πcorresponds to the displacement along the axis by step t, while the displacement of an angle α corresponds to the displacement along the axis by x, therefore:

$$\alpha = \frac{2\pi}{t}x \quad (2.27)$$

$$d\alpha = \frac{2\pi}{t}dx \quad (2.28)$$

Cường độ của tải trọng chiều trục liên tục :

$$q_x = \frac{dN_x}{dx} = p_N\frac{R_1^2 - R_2^2}{2}\frac{2\pi}{t} \quad (2.29)$$

In addition to the axial compression force, the axial pressure p_x also creates a continuous bending moment for the y and z axes, within the limit of the extremely small angle dα, determined by the following equation:

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$$dM_z = \int_{R_2}^{R_1} p_x dFy \quad (2.30)$$

Substitute (2.24) into (2.30) and the moment lever arm value y = r.sinα, we have :

$$dM_z = d\alpha \int_{R_2}^{R_1} p_N.\sin\alpha.r^2.dr = p_N \frac{R_1^3 - R_2^3}{3}\sin\alpha.d\alpha \quad (2.31)$$

The moment corresponding to a unit screw length or the intensity of the continuous bending moment about the z axis:

$$m_z = \frac{dM_z}{dx} = p_N \frac{R_1^3 - R_2^3}{3}\frac{2\pi}{t}\sin\frac{2\pi}{t}x \quad (2.32)$$

Similarly, the magnitude of the continuous bending moment about the y axis:

$$m_y = \frac{dM_y}{dx} = p_N \frac{R_1^3 - R_2^3}{3}\frac{2\pi}{t}\cos\frac{2\pi}{t}x \quad (2.33)$$

We analyze the pressure $p_r$and find the load causing it on the screw.In figure 2.2, it can be seen that the force p_rdF creates a torque, within the limit of angle dα, that quantity is equal to:

$$dM_x = d\alpha \int_{R_2}^{R_1} p_r.r.dr\frac{1}{\cos\beta}r = p_N.tg\beta\frac{R_1^3 - R_2^3}{3}d\alpha \quad (2.34)$$

Where : $p_r = p_N.\sin\beta$
Intensity of continuous torque:

$$m_x = \frac{dM_x}{dx} = p_N.tg\beta\frac{R_1^3 - R_2^3}{3}\frac{2\pi}{t} \quad (2.35)$$

Pressure p_r also creates a horizontal load along the axis whose intensity is $q_y$and a horizontal load along the z axis whose intensity is q_z.
The intensity of the continuous load can be found from the first derivative of the horizontal load

$$dQ_y = -d\alpha \int_{R_2}^{R_1} p_N.\sin\beta.r\frac{dr}{\cos\beta}\cos\alpha = -p_N.tg\beta\frac{R_1^2 - R_2^2}{2}\cos\alpha.d\alpha \quad (2.36)$$

Intensity of continuous horizontal load in $y_x$plane:

$$q_y = \frac{dQ_y}{dx} = -p_N.tg\beta\frac{R_1^2 - R_2^2}{2}\frac{2\pi}{t}\cos\frac{2\pi}{t}x \quad (2.37)$$

Intensity of continuous horizontal load in the $z_x$plane:

$$q_z = \frac{dQ_z}{dx} = -p_N.tg\beta\frac{R_1^2 - R_2^2}{2}\frac{2\pi}{t}\sin\frac{2\pi}{t}x \quad (2.38)$$

2-2-Horizontal and vertical bending moments

When bending horizontally and vertically, the elastic balance is characterized by an equation of the form:

$$E.J\frac{d^2v}{dx^2} = M + M_1 \quad (2.39)$$

where:
v - deflection of beam;
M - bending moment at section x due to longitudinal force;
M1 - bending moment at section x due to horizontal force;
J - moment of inertia of the screw conveyor cross section;
The moment due to the vertical force depends on the deflection v, its transformation law. Differentiating (2.39) we have:

$$E.J\frac{d^3v}{dx^3} = Q + Q_1 \quad (2.40)$$

where: Q = dM/dx - horizontal force due to vertical load;
Q1 = dM1/dx - horizontal force due to horizontal load;
According to Figure 2.3, it is shown that the vertical load acts on a screw with two fulcrums. From the diagram we see that:

$$Q = -S\frac{dv}{dx} + k\frac{x^2}{2!}\frac{dv}{dx} \quad (2.41)$$

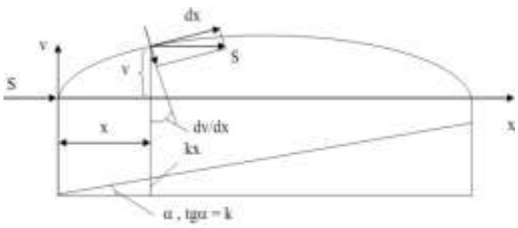

Figure 2.3. Dependence of horizontal force on vertical load

Thay giá trị Q ở (2.41) vào (2.40), ta có:

$$E.J\frac{d^3v}{dx^3} + S\frac{dv}{dx} - k\frac{x^2}{2!}\frac{dv}{dx} = Q_1 \quad (2.42)$$

where: S - reaction force on the left fulcrum;
k - proportionality factor for continuous axial load;

Differential equations can be solved by continuous approximation. Solving that equation according to the second approximate solution gives us the general equation of bending moment in the following moment form:

$$EJ\frac{d^2v}{dx^2} = M_1 - \gamma^2\frac{M_3}{3!} + \psi^2\frac{x_2}{2!}\frac{M_3}{3!} - \psi^2\frac{M_4}{4!} + \psi^2\frac{M_5}{5!} \qquad (2.43)$$

Where : γ^2 = S/EJ ; ψ^2 = k/EJ ;

$M_n/n!$ –the nth order moment due to horizontal load.

The nth order moment due to horizontal load is determined according to the theory of higher order moments. When bending horizontally and vertically, the equation of the bending moment in the expression usually takes the form:

$$E.J\frac{d^2v}{dx^2} = \left[\frac{B}{a} - \frac{A}{a^2}\right]f_1(x) - \gamma^2\left[\frac{B}{a} - \frac{A}{a^2}\right]f_2(x) + \psi^2\left[\frac{B}{a} - \frac{A}{a^2}\right]f_3(x) - \gamma^2.x.E.J.\theta_0 + \psi^2\frac{x_3}{3!}E.J.\theta_0 \qquad (2.44)$$

Where : $B = \frac{p_{\max}}{2}\frac{R_1^3 - R_2^3}{3}a;$

$$A = \frac{p_{\max}}{2}\frac{R_1^2 - R_2^2}{2}a.tg\beta;$$

$$f_1(x) = 1 - \cos ax;$$

$$f_2(x) = \frac{x^2}{2!} + \frac{1}{a^2}\cos ax - \frac{1}{a^2};$$

$$f_3(x) = 3\frac{x^4}{4!} + \frac{x^2}{2!}\frac{1}{a^2}\cos ax - \frac{x}{a^3}\sin ax + \frac{x}{a^4}(1 - \cos ax);$$

θ_0 - original rotation angle; $\alpha = 2\pi/t$;

The expression for the bending moment in the xy and xz planes is similar. While approximating, it is possible to limit it to the first term of expression (2.44), that is:

$$E.J\frac{d^2v}{dx^2} = \left[\frac{B}{a} - \frac{A}{a^2}\right](1 - \cos ax) \qquad (2.45)$$

2-3- Equivalent stress and strength test of screw conveyor

While calculating the approximate strength of the conveyor screw, it is necessary to pay attention to the following loads: the axial load continuously increases steadily from the left fulcrum (at the feed hole) to the right, the concentrated axial force is the reaction force. The fulcrum torque increases continuously and the concentrated torque on the fulcrum is equal to the sum of the torques

The load bearing diagram of the screw conveyor in Figure 2.4 shows the torque and longitudinal load as well as the diagram of torque and longitudinal force.

From the diagram of torque for dangerous cross-section it can be written:

$$M_x = \frac{m_x.l}{2} = \frac{p_{\max}.l}{2}\frac{R_1^3 - R_2^3}{2}a \qquad (2.46)$$

From the diagram of vertical force we have:

$$S = \frac{q_{\max}.l}{2} = \frac{p_{\max}.l}{2}\frac{R_1^2 - R_2^2}{2}a \qquad (2.47)$$

The equivalent stress according to the maximum tangential stress theory is determined by the formula: $\sigma_{td} = \sqrt{\sigma^2 + 4\tau^2}$

(2.48)

The stresses σ and τ are respectively equal to

$\sigma = S/F$; $\tau = M_x/W_c$; (2.49)

Where : F - screw cross-sectional area;

W_c - ultimate moment of resistance of screw cross section;Substituting the stress values we have:

$$\sigma_{td} = \sqrt{\left(\frac{S}{F}\right)^2 + 4\left(\frac{M_x}{W_c}\right)^2} \qquad (2.50)$$

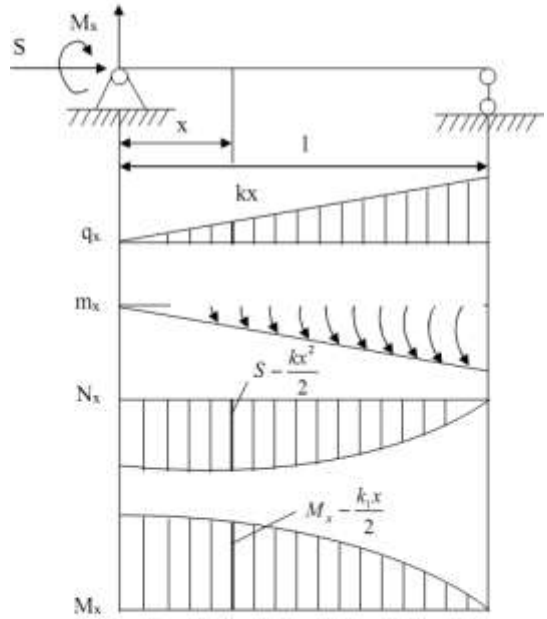

Figure 2.3. Vertical force and torque diagram

When designing a screw mixer, the torque and axial force are unknown, only p_{max} is known. It is possible to create a calculation formula to determine the stress when the R_1/R_2 ratio is determined. In mixers, the ratio of mixing screw

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radii ranges from 1.7 to 2.25, so taking a large ratio makes it easier to increase productivity.
With push screws, the ratio Mx to axial force S is determined by the formula (XVi-80)[6] :

$$\frac{M_x}{S} = \frac{2}{3}\frac{R_1^2 + R_1R_2 + R_2^2}{R_1 + R_2} tg\beta \quad (2.51)$$

$$S = \frac{3.M_x(R_1 + R_2)}{2tg\beta(R_1^2 + R_1^2 + R_2^2)} \quad (2.52)$$

Substitute the M_x and S values into the formula to determine:

$$\sigma_{td} = M_x\sqrt{\left[\frac{3(R_1+R_2)}{2tg\beta(R_1^2+R_1R_2+R_2^2)\pi R_2^2}\right]^2 + \frac{4}{\left(\frac{\pi R_2^3}{2}\right)^2}}$$

(2.53)

Đặt giá trị M_x ở công thức (2.46) vào công thức (2.53) ta có:

$$\sigma_{td} =$$

$$\frac{p_{max}.l}{2} tg\beta \frac{R_1^3 - R_2^3}{3}\frac{2\pi}{t}\sqrt{\left[\frac{3(R_1+R_2)}{2tg\beta(R_1^2+R_1R_2+R_2^2)\pi R_2^2}\right]^2 + \frac{16}{(\pi R_2^3)^2}}$$

(2.54)

Working length of screw conveyor l = m.t, where m is the number of turns of the screw. It is possible to plot the variation of σtd depending on the screw path elevation angle, on different R_1/R_2 ratios, on the given working pressure p_{max} and the selected number of turns m.

2-4- Screw conveyor blade helix strength

The strength of the conveyor screw should be calculated under the conditions of maximum pressure p_{max}, perpendicular to the spiral surface. The conveyor screw forms a helix in the mixing chamber; With a small difference, a helix can be considered as a circular plate attached along the inner diameter to the shaft. Force N is the reaction force toward the helix.

$$N = p_{max}.\pi(R_1^2 + R_2^2) \quad (2.56)$$

To determine the horizontal force, let's study the equilibrium condition where the central part of the plate is separated as a cylindrical section with radius r (Figure 2.5).

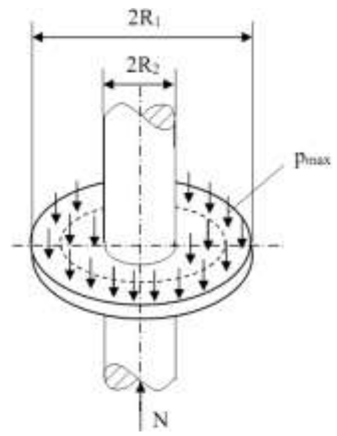

Figure 2.5. Approximate diagram to calculate screw conveyor blade helix

From the equilibrium condition, when r / R_2, then:

$$Q = \frac{p_{max}\pi(r^2 - R_2^2) - N}{2\pi.r} = \frac{p_{max}}{2}\left(r - \frac{R_1^2}{r}\right)$$

(2.57)

The rotation angle of the normal θ is determined according to the formula (XVI - 12)[6]:

$$\theta = C_1 r + \frac{C_2}{r} - \frac{p_{max}}{2Dr}\int_{R_2}^{r} r\left[\int_{R_2}^{r}\left(r - \frac{R_1}{r}\right)dr\right]dr$$

(2.58)

After integrating and substituting limits, we have:

$$\theta = \left(C_1 r + \frac{C_2}{r} - \frac{p_{max}.r^3}{16D}\right).$$

$$\left(1 + \frac{R_2^4}{r^4} - 2\frac{R_2^2}{r^2} + 2\frac{R_1^2}{r^2} - 2\frac{R_1^2R_2^2}{r^4} - 4\frac{R_1^2}{r^2}\ln\frac{r}{R_2}\right) \quad (2.59)$$

the derivative of θ

$$\theta' = \left(C_1 - \frac{C_2}{r^2} - \frac{p_{max}.r}{16D}\right).$$

$$\left(3\frac{R_2^4}{r^4} - 2\frac{R_2^2}{r^2} - \frac{R_1^2}{r^2} + 2\frac{R_1^2R_2^2}{r^4} - 4\frac{R_1^2}{r}\ln\frac{r}{R_2}\right)$$

(2.60)

To determine the integration constants C_1 and C_2, we use the limit condition when r = R_2, meaning that where the spiral is tightly coupled to the shaft, the normal rotation angle θ is 0. In formula (2.59) set the value r = R_2 and derive the same term.

$$C_1R_2^2 + C_2 = 0 \quad (2.61)$$

The second limiting condition is derived when r = R_1, bending moment M_r = 0

$$M_r = D\left(\theta' + \mu\frac{\theta}{R_1}\right) = 0 \qquad (2.62)$$

$$\theta = \left(C_1 R_1 + \frac{C_2}{R_1} - \frac{p_{max}.R_1^3}{16D}\right).\left(3 + \frac{R_2^4}{R_1^4} - 4\frac{R_2^2}{R_1^2} - 4\ln\frac{R_1}{R_2}\right) \qquad (2.63)$$

$$\theta' = C_1 - \frac{C_2}{R_1^2} - \frac{p_{max}.R_1^2}{16D}\left(1 - \frac{R_2^2}{R_1^2} - 4\ln\frac{R_1}{R_2}\right) \qquad (2.64)$$

$$C_1 - \frac{C_2}{R_1^2} - \frac{p_{max}.R_1^2}{16D}\left(1 - \frac{R_2^4}{R_1^4} - 4\ln\frac{R_1}{R_2}\right) + \mu\left[C_1 + \frac{C_2}{R_1^2} - \frac{p_{max}.R_1^2}{16D}\left(3 + \frac{R_2^4}{R_1^4} - 4\frac{R_2^2}{R_1^2} - 4\ln\frac{R_1}{R_2}\right)\right] = 0 \qquad (2.65)$$

Solving the system of equations (2.61) and (2.65), we find the integration constants C_1 and C_2.

$$C_1 = \frac{p_{max}.R_1^2}{16D}\frac{1+3\mu-\alpha^{-4}(1-\mu)-4\mu\alpha^{-2}-4(1+\mu)\ln\alpha}{1+\mu+\alpha^{-2}(1-\mu)}$$

$$C_2 = \left(\frac{p_{max}.R_1^2.R_2^2}{16D}\right)\left(\frac{1+3\mu-\alpha^{-4}(1-\mu)-4\mu\alpha^{-2}-4(1+\mu)\ln\alpha}{1+\mu+\alpha^{-2}(1-\mu)}\right)$$

Where : $\alpha = R_1/R_2$

Put the values $C_1$and C_2into the formulas (2.59) and (2.60) and denote $r/R_2 = \lambda$there is

$$\theta = \left(\frac{p_{max}.R_1^2.r}{16D}\right).\left(\frac{1+3\mu-\alpha^{-4}(1-\mu)-4\mu\alpha^{-2}-4(1+\mu)\ln\alpha}{1+\mu+\alpha^{-2}(1-\mu)}\right).(1-\lambda^{-2}) - \frac{p_{mai}.r^3}{16D}(1+\lambda^{-4}-2\lambda^{-2}+2\alpha^2\lambda^{-2}-2\alpha^2\lambda^{-4}-4\alpha^2\lambda^2.\ln\lambda)$$

$$\theta' = \left(\frac{p_{max}.R_1^2}{16D}\right)\left(\frac{1+3\mu-\alpha^{-4}(1-\mu)-4\mu\alpha^{-2}-4(1+\mu)\ln\alpha}{1+\mu+\alpha^{-2}(1-\mu)}\right)(1+\lambda^{-2}) - \frac{p_{mai}.r^2}{16D}(3-\lambda^{-4}-2\lambda^{-2}-2\alpha^2\lambda^{-2}+2\alpha^2\lambda^{-4}-4\alpha^2\lambda^2.\ln\lambda)$$

Set:

$$A = \frac{1+3\mu-\alpha^{-4}(1-\mu)-4\mu\alpha^{-2}-4(1+\mu)\ln\alpha}{1+\mu+\alpha^{-2}(1-\mu)} \qquad (2.66)$$

So $M_r$and M_τ :

$$M_r = \frac{p_{max}.R_1^2}{16}A(1+\lambda^{-2}+\mu-\mu\lambda^{-2}) - \frac{p_{max}.r^2}{16}[3+\mu-\lambda^{-4}(1-\mu)(1-2\alpha^2) - 2\lambda^{-2}(1+\mu+\alpha^2-\mu\alpha^2)-4(1+\mu)\alpha^2\lambda^{-2}\ln\lambda] \qquad (2.67)$$

$$M_\tau = \frac{p_{max}.R_1^2}{16}A(1-\lambda^{-2}+\mu+\mu\lambda^{-2}) - \frac{p_{max}.r^2}{16}[1+3\mu+\lambda^{-4}(1-\mu)(1-2\alpha^2) + 2\lambda^{-2}(\alpha^2-1-2\mu-2\mu\alpha^2)-4(1+\mu)\alpha^2\lambda^{-2}\ln\lambda] \qquad (2.68)$$

Các ứng suất được xác định như sau :

$$\sigma_r = \pm\frac{6M_r}{h^2} \quad ;\sigma_\tau = \pm\frac{6M_\tau}{h^2} \qquad (2.69)$$

at the inner borderr = R_2 và $\lambda = 1$

at the outer border r = R_1 và $\lambda = \alpha$

Bending moments at the inner contour

$$M_r = \left(\frac{p_{max}.R_1^2}{8}\right).\left(\frac{1+3\mu-\alpha^{-4}(1-\mu)-4\alpha^{-2}-4(1+\mu)\ln\alpha}{1+\mu+\alpha^{-2}(1-\mu)}\right)$$

$$M_\tau = \left(\frac{p_{max}.R_1^2}{8}\mu\right).\left(\frac{1+3\mu-\alpha^{-4}(1-\mu)-4\mu\alpha^{-2}-4(1+\mu)\ln\alpha}{1+\mu+\alpha^{-2}(1-\mu)}\right) \qquad (2.70)$$

Moments at the outer contour

$$M_r = 0$$

$$M_\tau = \left(\frac{p_{max}.R_1^2}{16}\right)\left(\frac{1+3\mu-\alpha^{-4}(1-\mu)-4\mu\alpha^{-2}-4(1+\mu)\ln\alpha}{1+\mu+\alpha^{-2}(1-\mu)}\right).[1+\mu-\alpha^{-2}(1-\mu)] - \left(\frac{p_{mai}.R_1^2}{16}\right).[3+\mu+\alpha^{-4}(1-\mu)-4\alpha^{-2}-4(1+\mu).\ln\lambda] \qquad (2.71)$$

III. CORROSION STABILITY ANALYSIS OF SCREWDRIVERS

3-1-Stability analysis

The screw conveyor jig diagram is presented as shown in Figure 3.1, in which:

1: Screw tail support
2: Observation cover
3: Screw wing
4: Screw head support
5: Connect the elastic shaft
6: belt
7: Electric motor
8: Gear reduction box
9: Screw

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10: Screw trough
11: Connect the intermediate shaft
12: Intermediate shaft support
13: Unloading door
14: Screw trough cover
15: Loading inlet

Productivity : $Q=6m^3/h$	Working coefficient/year: $K_n=0,79$
Transportation tilt angle : $\alpha=10^0$	Initial drag coefficient: $K_{bd}=1,6$
Transportation length: L=21(m)	Working time : 9 years
Working coefficient/day : $K_{ng}=0,7$	Constant load, 1-way rotation

Initial data:

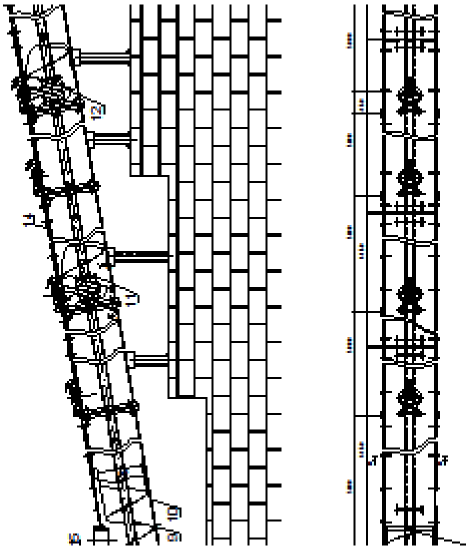

Figure 3.1a. Screw conveyor installation diagram

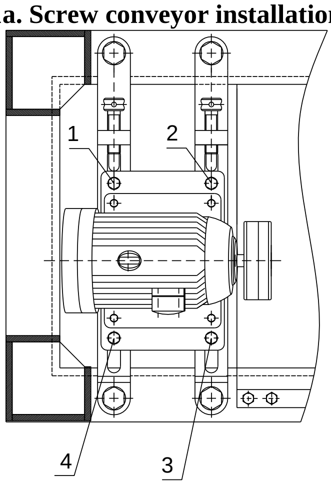

Figure 3.1b. Install the motor into the machine

3-1-1- Force acting on the base of the machine

During operation, the belt transmission applies a force F_r and force F_0 to the motor shaft. This force acts on the bolts as shown in Figure 3.2.

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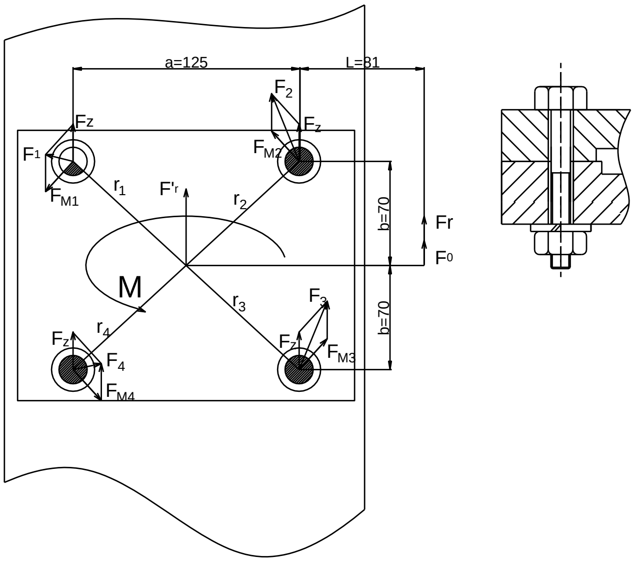

Figure 3.2. Force acting on the base of the machine

Moving the force F_r to the center of gravity of the joint gives amoment and a force
$F'_r = F_r + F_0$ (2.72)
The moment acting on the shaft has a value.

$$M = \left(L + \frac{1}{2}a\right).F \quad (2.73)$$

Under the effect of force F'_r, each bolt bears a value F_Z.

$$F_Z = \frac{1}{4}F_r' \quad (2.74)$$

Dưới tác dụng của mô men M các bu lông chịu các lực tương ứng:
$F_{M1}, F_{M2}, F_{M3}, F_{M4}$
có chiều như hình vẽ 2.8 và có giá trị.

$$F_{Mi} = \frac{M.r_i}{\sum r_i^2} \quad (2.75)$$

The radius is determined:

$$r_1 = r_2 = r_3 = r_4 = \frac{1}{2}.\sqrt{a^2 + (2b)^2} \quad (2.76)$$

From figure 2.8 $\longrightarrow F_{Max}$ can only be $F_2 = F_3$

$$F_3^2 = F_Z^2 + F_{M3}^2 + 2.F_z.F_{M3}.\cos(\vec{F}z.\vec{F}M3) \quad (2.77)$$

$$\cos(\vec{F}z.\vec{F}M3) = \cos\theta_3 = \frac{a}{2.r_3}$$

From tensile conditions:

$$\rightarrow \left[\sigma_k\right] = \frac{1,3.4.V}{\pi.d_3^2} \le \left[\sigma_k\right] \rightarrow d_3 \ge \sqrt{\frac{1,3.4.V}{\pi.\left[\sigma_k\right]}} \quad (2.78)$$

where $V = \frac{k.F}{i.f}$ (2.79)

With i being the contact surface i= 1; Friction coefficient f=0.2 Safety coefficient k=2

$$d_3 \ge \sqrt{\frac{1,3.4.k.F_{max}}{\pi.f.\left[\sigma_k\right]}} \quad (2.80)$$

3-1-2-Calculate screw stability

Calculate the power on the screw conveyor

The capacity of the screw conveyor is determined according to the formula:

$$P = \frac{QH}{360} + C_0\frac{QL}{360} \quad (2.81)$$

Where:
Q- Productivity of screw conveyor (Ton/hour).
L- Transport length of material in the horizontal direction (m).
C_0- Resistance coefficient. With material being iodized salt C_0=2.5.
H- Vertical material transportation height (m).
$H = L.\sin\alpha = 21.\sin 10^0 = 3,65(m)$.

$$P = \frac{QH}{360} + C_0\frac{QL}{360} = \frac{6.1,2.3,65}{360} + 2,5.\frac{6.1,2.21}{360} = 1,123(Kw) \quad (2.82)$$

Torque on the screw

Derived from the expression for screw conveyor productivity:

$$Q = \frac{60\pi}{4}D^2.S.n.\rho.\varphi.C \quad (2.83)$$

In which:
D – outer diameter of screw conveyor, (m);
S – twist step, (m);
n – number of rotations of the screw tải, (vg/ph);

$$n = \frac{k_v}{\sqrt{D}}$$

ρ – density of the material, (T/m^3); with iodized salt $\rho = 1{,}12 \div 1{,}28$ (T/m^3). $\rho = 1{,}2$ (T/m^3).

φ – containment coefficient, with iodized salt φ =45.

C – The coefficient takes into account the angle of inclination of the loading screw. with $\beta = 10^0$ chọn $C = 0{,}8$.

Thay vào Q và biến đổi ta có.

$$D = \left(\frac{Q}{37,7.\varphi.C.S.\rho}\right)^{\frac{2}{5}} = \left(\frac{6.1,2}{37,7.45.0,4.0,8.1,2}\right)^{\frac{2}{5}}$$

$$= 0{,}16496(m) = 164{,}96(mm)$$

Choose D according to the standard, with D= 200(mm).

Torque acting on conveyor screw T_v(Nmm) Determined by the formula:

$$T_v = 9{,}55.10^6 \frac{P}{n_v} \quad (2.85)$$

In there:
P- Power on screw conveyor (Kw).
nv- Rotation of screw conveyor (Rpm).
Number of rotations of the screw conveyor

$$n = \frac{k_v}{\sqrt{D}} = \frac{45}{\sqrt{0,2}} = 101(rpm) \Rightarrow$$

$$T_v = 9{,}55.10^6 \frac{P}{n_v} = 9{,}55.10^6 \frac{1{,}123}{101} = 103864(Nmm)$$

$$T_v = 103864\ (Nmm) = 103{,}86\ (Nm)$$

Screw axial force

$$F_{av} = \frac{T_v}{R.tg(\alpha + \gamma)} \quad (2.86)$$

there:
R- Distance of the point of applying the friction force of the material with the screw blade to the axis of the screw conveyor (mm); $R = (0{,}3 \div 0{,}4).D = (0{,}3 \div 0{,}4).200 = 60 \div 80$ (2.87)

=> chose R=70.

α - The angle of elevation of the screw helix (degrees), determined according to the formula;

$$tg\alpha = \frac{p}{2\pi R} = \frac{1{,}123}{2.3{,}14.70} = 0{,}0026 \Rightarrow \alpha = 0^0 8' 46'' \quad (2.88)$$

γ - Friction angle of transported material with screw blade (degrees): $tg\gamma = f$.

With f the friction coefficient of the transported material with the screw blade.
For the transport material being iodized salt, choose f=1.=> $tg\gamma = f = 1 \Rightarrow \gamma = 45^0$ (2.89)

$$F_{av} = \frac{T_v}{R.tg(\alpha + \gamma)} = \frac{106184{,}65}{70.tg(0^0 8' 46'' + 45)} = 1509{,}646(N) \quad (2.90)$$

Horizontal load acts on the screw.

The horizontal load acting on the screw is determined as follows:

$$P_n = \frac{2.T_v.l}{k.D.L}\ (N) \quad (2.91)$$

In there:
L: Screw length, L =21(m).
l: Distance between supports, l = 3 (m).
Tv: Torque on the screw $T_v = 103864{,}29\ (Nmm) = 103{,}86\ (Nm)$

k: Coefficient that takes into account the force-bearing radius, k = (0.7 – 0.8) choose k = 0.7
D: Screw diameter, D = 0.2 (m).

$$\text{So: } P_n = \frac{2.T_v.l}{k.D.L} = \frac{2.103{,}86.3}{0{,}7.0{,}2.21} = 211{,}96\ (N)$$

* Vertical load uniformly distributed on the screw shaft is:

$$p_d = \frac{F_{av}}{L} = \frac{1509{,}646}{21} = 71{,}89\ (N/m) \quad (2.92)$$

* The horizontal load is evenly distributed on the screw shaft:

$$p_n = \frac{P_n}{l} = \frac{211{,}96}{3} = 70{,}65\ (N/m) \quad (2.93)$$

* Torque distributed evenly on the screw is:

$$M_o = \frac{T_v}{L} = \frac{103{,}86}{21} = 4{,}95\ (N) \quad (2.94)$$

Check torsional deformation conditions

Torsional deformation is determined according to the formula:

$$\varphi = \int_0^l \frac{M_z d_z}{GJ_p} = \frac{1}{GJ_p}\int_0^l M_z d_z = \frac{1}{GJ_p}\int_0^l M_0.zd_z = \frac{1}{GJ_p}\frac{M_0 l^2}{2}$$

where:

$$M_z = M_0.z$$

$$G = 8.10^3 (KN/cm^2) = 8.10^{10} (N/m^2)$$

The material used to make conveyor screws is steel

$$J_p = 0{,}1.D^4(1-\eta^4)\ ;\ \eta = \frac{d}{D}$$

To ensure productivity, choose η = 0,5
So:

$$\varphi = \frac{4,95.21^2}{8.10^{10}.0,1.0,2^2(1-0,5^4)} = 7,3.10^{-6}$$

according to [6]. The system guarantees the torsional deformation conditions

3-1-3-Check the stress at the joints

Select the coupling for the output shaft of the gear box and the screw input shaft. To ensure stable transmission of torque from the output of the gear box shaft to the screw conveyor, we choose the coupling between the two shafts as an elastic coupling. Thanks to the elastic part, it is able to reduce shock and vibration, prevent resonance caused by torsional vibrations and compensate for shaft misalignment.

Couplings have elastic parts made of non-metallic materials, so they are cheap and simple, and are used to transmit small and medium torques.

Couplings are standard details, so in design we often rely on the torque Tt determined by the following formula to choose the coupling size.

$T_t = k.T \le [T]$ (2.97)

In there:

T : nominal torque : T = 103864.29(Nmm)

k: Working mode coefficient, depends on the type of working machine, look up table 16.1 [8] with the working machine being a screw conveyor, we choose k = 1.8

$\Rightarrow T_t$ =1,8. 103864,29= 186955,72 (N.mm)

[T]: allowable torque. according to table 16.10a [8], We have [T] = 500 (N.m) = 500 000 (N.mm) (Satisfied)

The diameter of the coupling is d = 56 mm

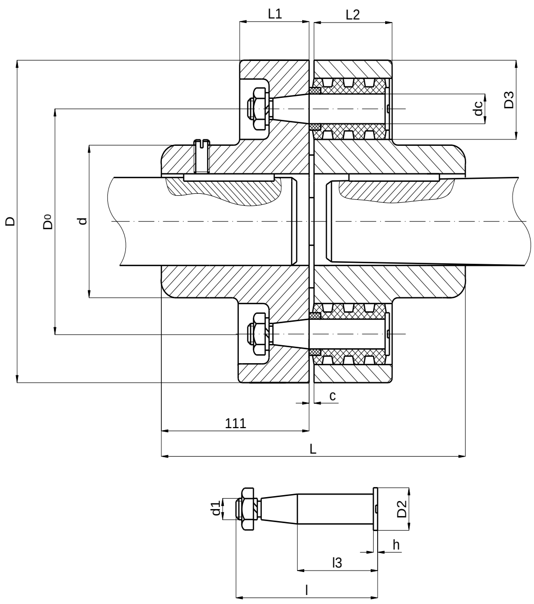

Figure 3.3. The elastic coupling

+ Check the stamping strength conditions of the elastic ring and the durability conditions of the pin according to the formula:

$$\sigma_d = \frac{2.k.T}{Z.D_0.d_c.l_3} \le [\sigma]_d$$
$$\sigma_u = \frac{k.T.l_0}{0,1.d_C^3.D_0.Z} \le [\sigma]_u \quad (2.98)$$

In there:

k: Working mode coefficient, looking up table 16.1[8] we get k = 1.8

$l_0 = l_1 + l_2/2$ = 34 + 15/2= 41,5 (mm)

$[\sigma]_d$: allowable stamping stress of rubber ring

$[\sigma]_d = 2 \div 4$ (MPa)

$[\sigma]_u$: allowable bending stress of the pin

$[\sigma]_u = 60 \div 80$ (MPa)

Substituting the parameters into the (2.98), we have:

$$\sigma_d = \frac{2.1,8.103864,29}{8.130.14.28} = 0,92 < [\sigma]_d = 2(\text{MPa})$$

$$\sigma_u = \frac{1,8.103864,29.62}{0,1.14^3.130.8} = 40,6 \le [\sigma]_u = 60(\text{MPa})$$

Thus, according to [8] the elastic ring satisfies the stamping strength condition and the pin satisfies the bending strength condition.

3-2-Analyze the wear process of conveyor screw blades

Metal corrosion is a phenomenon of self-corrosion and gradual surface destruction of metal materials due to chemical or electrochemical effects between the metal and the external environment with which the metal is in contact. The possibility of corrosion depends on many factors of the metal material, environmental properties, temperature, time, pressure, etc.

Classification of corrosion

* Based on the corrosion process, corrosion is divided into:

1. chemical corrosion
2. electrochemical corrosion.

* Based on the environment Depending on the environment, people are divided into:

1. Corrosion in gases: oxygen, sulfur gas, H2S gas,...
2. Corrosion in air: Corrosion in wet air, corrosion in humid air, corrosion in dry air.
3. Corrosion in soil.
4. Corrosion in liquids (alkaline, acid, salt,... Thus:

The form of cavitation corrosion is due to the contact movement between solid surfaces and the movement of liquids and gases. (chemical corrosion); Corrosion caused by contact with media such as acids, bases, salts and electrical agents is called electrochemical corrosion.

In the iodized salt mixing line. The screw conveyor transports NaCl salt in an environment mixed with moisture, so the material used to make the screw conveyor is mainly subject to electrochemical corrosion.

Corrosion remedies

a. Design solutions

* Choose rolling or sliding friction type:
- Rolling friction: limited load bearing, difficult to ensure concentricity, easy to slip, but small sliding speed, small μ coefficient, short axis.
- Sliding friction: large μ, long axis, but good concentricity, difficult to slide, high sliding speed.
* Choose the shape and size of the detail:

The shape and size of the part affect the specific pressure, durability, wear resistance, fatigue resistance... Therefore, when designing, it is necessary to enhance the perfect structure, size, and geometric shape. of the detail, the initial gap.

To ensure wear resistance, it must be based on the condition: contact surface pressure is less than the allowable limit.

$$p = \frac{P}{S_{tx}} < [p]$$

P-load in the normal on the contact surface

Stx - contact surface area

For screw conveyors, the trend is to increase the shaft diameter d to shorten the shaft and avoid bending and sagging.

Structural design, good cooling plan

b. Technological solutions

4-1-Choose CeraMetal as the material to make iodized salt mixing screws

CeraMetal has developed a surface hardening system to protect conveyor screws against wear, which promises to extend service life, thereby providing significant cost savings.

CeraMetal can design and manufacture screw conveyors used in ports to transfer cement clinker into large container ships. Previously, screw conveyor blades manufactured from 10mm thick hardened steel plates were completely destroyed after loading 100,000 tons of material. The consequence is huge costs due to frequent screw replacement. This system includes 6 screw conveyors with a screw blade diameter of about 760mm and a length of up to 7.35 meters used in parallel to directly load clinker - a highly abrasive product into the transport ship's hull. Applications involving the selection of surface hardening

The quality of part machining greatly affects wear and damage of the part, plating or hardening the working surface of the part combined with suitable bearings to prevent wear:

* Increase surface durability:
- Cold hardening: shot blasting, rolling, pressing...
- Heat treatment: quenching, tempering, thermalization, absorption of C, N, metals
- Plating (not used on parts subject to dynamic loads)
* Surface protection:
- Surface plating to prevent oxidation, tin coating, plastic.
* Improve processing quality
+ The processed gloss is close to the working gloss.
+ Cone and oval accuracy

c. Mode of use

- Working mode: must be based on conditions to ensure normal friction: $p<p_{th}$, $v<v_{th}$. (avoid overloading and overspeeding).
- Qualifications and habits of system operators
- Timely technical maintenance care: daily and periodically at the right time. If used beyond the prescribed time limit, it will cause severe damage and destruction. Failure to run is not allowed when the part has reached the limit size.

In this study, we chose the material CeraMetal special steel to process the screw conveyor blades.

IV. SOLUTIONS TO IMPROVE THE QUALITY OF MANUFACTURING SCREWDRIVERS MIXING IODED SALT

materials to withstand various wear conditions depend on the locations in the system. Abrasion due to friction and abrasion by the loading material is mainly, but the areas of the inlets of each area are subjected to impact at operating speeds of up to 2000 rpm, inevitably erosion occurs. due to impact. Therefore, the work surface requires more than one hard material and multiple application processes. CeraMetal is so effective, the hard coating material just "polishes" on without significant wear.

Conveying screws using CeraMetal material can last up to 5 times longer than those originally manufactured with hardened steel. This results in significant savings due to reduced production downtime. At the same time, with production costs not exceeding the initial costs, the overall cost savings of this solution are very significant.

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Figure 4.1. The screw conveyor is made with CeraMetal's hard surface material

Figure 4.2. Only part of the hard surface of the screw is "polished".

Figure 4.3. The surface of the conveyor screw is “polished”

Figure 4.4. Part of the screw conveyor's surface

Manufacturing method when using Cerametal wear-resistant plates:

+ Recommended to use plasma cutting. Arc cutting is also possible
+ Shaping can be done as easily as with soft steel. Generally the hard surface must be inside.
+ Welding of mild steel base plates with other types of steel can be performed by conventional methods without the need for heating or special measurements. 7018 welding electrodes are used for this, ensuring that these welds do not affect the hard surface. Connecting hard surfaces can be accomplished with CeraMetal tube solder or hard coating solder wire.

4-2-Method of assembling screw conveyor parts

4.2.1. The top side of the shaft (Motor connection side), the end of the shaft and the screw connection

The top side of the shaft

The top side of the shaft is connected to the drive motor through a bearing to create torque for the screw conveyor. Therefore, the shaft end must be machined with high quality steel to create torque and increase bending ability. For screw conveyors with long lengths or heavy loads, alloy steel, high carbon steel and thoroughly tempered are often used or connected between screw conveyors with 3 sturdy bolts. To facilitate assembly, the bore and keyways must be machined accurately (Figure 4.5).

The end of the shaft

The end of the screw is equipped with a closed tolerance joint operating in a bearing, the screw holes are interchangeable to facilitate assembly and replacement (Figure 4.5).

The screw connection

The joints connect adjacent screw segments, and transmit rotation to each other. Therefore, the type of steel used for processing needs to be carefully selected and properly heat treated to ensure surface hardness, solidity, and durability. For screw conveyors with long lengths or heavy loads, alloy steel, high carbon steel and thoroughly tempered are often used or connected between screw conveyors with 3 sturdy bolts. Drilled guide holes ensure allowable tolerances, convenient for assembly. Cladding pieces should be placed between the joints and fastened to the joints through bolts. This is especially convenient when screws need to be removed for repair or

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maintenance without affecting other parts (Figure 4.6).

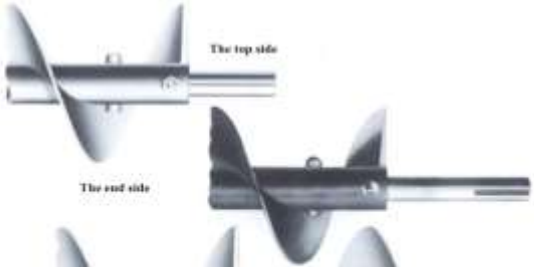

Figure 4.5. The top and the end of the shaft

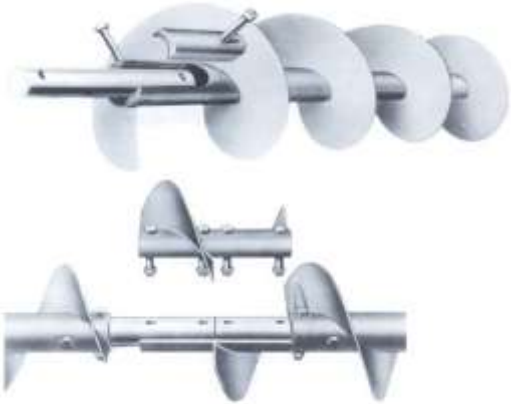

Figure 4.6. The screw connection

Trough seals, shaft bearings and bearings

Trough end caps are made of gray cast iron, they often come with shaft bearings and bearings and are placed at both ends of the trough. Aims to prevent dust and smoke from outside coming in or vice versa. Bearings both support the shaft and help the screw conveyor shaft rotate smoothly around the bearing. Shaft and ball bearings are also commonly made of gray cast iron. However, if the load is large, you can use an anti-friction alloy (Copper alloy coated with babit anti-friction material).

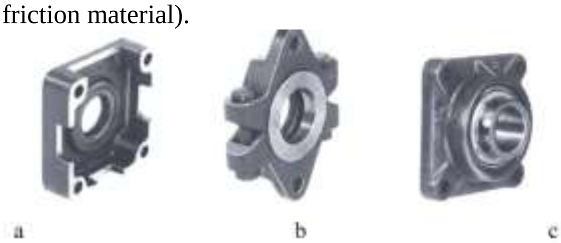

Figure 4.7. a: Trough cover plate
b: Shaft bearing
c: Bearings

Trough of screw conveyor

The screw conveyor trough plays the role of guiding material flow and protecting the screw conveyor. They are welded with corrugated iron sheets that are highly resistant to abrasion. There is a lid on top, on the lid and on the bottom there are holes for feeding and discharging. Some types are also equipped with wheels at the bottom to facilitate movement (Figure 4.8).

Figure 4.8. Trough of screw conveyor

Assemble the screw conveyor into the trough, shaft bearing, bearing and let the screw conveyor work

After machining the separate parts, we assemble the conveyor screw into the trough, assemble the shaft bearing systems, bearings, two trough seals, and mount the drive motor and drive system. Finally, put the system into testing, calibrating and running in real time.

4-2-3-Operation and maintenance of screw conveyor system

Operation

- When the machine is operating, you must know which machine parts operate first, which parts operate later, and which parts operate simultaneously. Conversely, when the machine stops operating, which part stops first and which part stops last?
- When feeding, it is necessary to coordinate smoothly and orderly according to the specified ratio and productivity.
- When there is an incident, the operator must be alert, active and clearly understand the operating problem to handle it according to principles.
- To achieve the required productivity as well as the desired rate, the worker must be able to control the entire system completely, avoiding wasted machine downtime and running time.
- It is necessary to have a team of skilled workers, meeting the necessary needs: incidents need to be handled promptly, the damage process must be known in advance for refurbishment, repair or replacement. In addition, a mechanical team is needed to inspect and conduct replacement inspections when necessary.

Maintenance

- After fabrication and assembly is complete, there need to be protection methods to prevent corrosion in the environment, prevent rust, dust... Temporary or long-term measures can be used as follows:
+ Paint, polish, plating...

+ Use anti-corrosion materials
+ Anti-rust lubrication
....
- Working parts must be covered, carefully lubricated, cooled, and lubricated with bearings as well as bearing parts.
- Check machinery and equipment at connected working places and load-bearing places for any problems. If so, adjust immediately or report to the technical department for timely adjustment.
- In addition to the above issues, it is necessary to check and plan repairs periodically. Many details cannot be checked, we must have time to periodically check when disassembling the machine.
- It is necessary to repair, change and repair immediately during periodic inspection according to regulations of damaged details.

V. DISCUSSION

In this study, we have:
+ Calculate the screw conveyor placed on its side in the iodized salt mixing line. Check durability, stress, Calculate force and moment acting on shaft and screw blade. The machine has a simple structure, but still ensures the machine works stably, ensuring the designed productivity.
+ Research the corrosion and abrasion process of mixed materials on screw conveyor blades. Effect of friction force on the wear process of screw conveyor blades. From there, a plan for choosing materials for manufacturing screw conveyors is proposed.
+ Propose a plan to connect the screw conveyors, a plan for installation, operation, and maintenance of the screw conveyors.

The author proposed a plan to choose Cerametal material to process screw conveyor blades. Conveying screws using CeraMetal material can prolong their service life 5 times compared to those originally manufactured with hardened steel, at a reasonable price, resulting in a quick return on investment.

Also in this chapter, the author proposed a number of options for assembling parts of the screw conveyor system: Screw head, screw end, trough... especially screw conveyor joints. When the working length of the screw conveyor is large, it is necessary to connect many screw conveyor segments together. The screw conveyor coupling will connect adjacent screw conveyor segments, and transmit rotational motion to each other. Therefore, the type of steel used for processing needs to be carefully selected and properly heat treated to ensure surface hardness, solidity, and durability. For screw conveyors with long lengths or heavy loads, alloy steel, high carbon steel and thoroughly tempered are often used or connected between screw conveyors with 3 sturdy bolts. Drilled guide holes ensure allowable tolerances, convenient for assembly. Cladding pieces should be placed between the joints and fastened to the joints through bolts. This is especially convenient when screws need to be removed for repair or maintenance without affecting other parts. To further improve the productivity and working life of the screw conveyor, the author also proposes a number of options for operating and maintaining the screw conveyor system.

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