The analysis and research of the roller rotation resistance

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Abstract

In order to better understand the roller rotation resistance, this article respectively to the bearing resistance moment, labyrinth seal resistance moment and resistance moment of sealing ring analysis and calculation, it is concluded that the hosting rotary torque calculation formula of bearing for the rotary thermal analysis at the same time, the temperature rise is given as a function of roller rotation speed, and through the MATLAB software for roller rotation torque drawing, it is concluded that the roller rotation torque in hosting the objective law under the influence of the rotational speed and load, provides a certain theoretical basis for roller design.

Keywords

Rotational resistance moment, thermal analysis, rotating speed, load.

1. Introduction

The roller is an important part of the conveyor, and the total weight is about 30% to 40% of the whole machine. The quality of the roller will directly affect the operating condition of the belt conveyor [1]. Roller rotation torque is an important index to measure the performance of roller, directly affect the driving power of belt conveyor, so the calculation of reasonable roller resistance moment, to improve the quality of the roller, reduction of conveyor drive power is of great significance.

2. Calculation of rotary resistance moment of roller

The rotational resistance torque of the roller mainly includes the rotational resistance torque generated by the friction of the bearing group, the rotational resistance moment caused by the shearing viscosity of the grease in the labyrinth ring, and the rotational resistance torque generated by the rotation of the sealing ring [2].

2.1 Bearing rotational resistance torque

The Harris formula shows that the rotating resistance moment of the bearing group is composed of two parts [3-4], the rotating resistance moment related to the bearing load M_0 and the rotation resistance moment irrelevant to the bearing load M_1.

M_0 is mainly with roller speed, bearing type and grease, the formula is:

$$M_0 = 1.42\times10^{-6} f_0(v\cdot n)^{\frac{2}{3}}\cdot d_m^3 \tag{1}$$

In the formula: v is the kinematic viscosity of grease; n is the rotational speed of the roller; f_0 is considering the bearing structure and grease-related coefficient; d_m is the average diameter of the bearing, $d_m = d + D$; d is the inner diameter of the bearing; D is the outer diameter of the bearing.

M_1 is mainly related to elastic hysteresis and contact surface sliding friction loss, the formula is:

$$M_1 = f_1 p_1 d_m \tag{2}$$

In the formula: p_1 is Radial load for the bearing; f_1 is load factor for the bearing.
The bearing torque resistance formula M is:

$$M = M_0 + M_1 \tag{3}$$

1.1.1 Bearing rotation thermal analysis

In actual operation, the idler roller will keep rotating with the conveyor running, and the long-term rotation will generate a lot of heat between the bearing rings. Due to poor grease flow, the heat can not be circulated to the outside world, the heat will be transmitted to the bearing ring, bearing seat, support shaft, bearing components due to different materials, will produce different degrees of deformation when heated, the inner and outer rings Of the deformation will cause changes in bearing work clearance, and changing the preload when the transition, the final will cause the bearing rotation resistance becomes larger. Therefore, the thermal analysis of the bearing is crucial. Friction friction thermal formula [5]:

$$Q = 1.02\times10^{-4} M\cdot n \tag{4}$$

Will type (3) into the above formula:

$$\begin{aligned} Q = {} & 1.491\times10^{-10} f_0(\nu)^{\frac{2}{3}}(n)^{\frac{5}{3}}\cdot d_{\mathrm{m}}{}^{3} \\ & +1.05\times10^{-4} f_1 p_1 d_m\cdot n \end{aligned} \tag{5}$$

From the formula (5) we can see with the roller speed increases, the heat generated by the bearing will continue to rise, with the bearing internal temperature increases, the characteristics of the grease will be changed accordingly, when the bearing temperature exceeds grease droplets At the point temperature, the grease begins to drip when heated and melted, causing the oil film to break down, resulting in direct contact between the ball and the inner and outer rings, which in turn causes the bearing to be damaged. Therefore, temperature changes should be strictly monitored during use.

Thermal energy formula：

$$Q_1 = c\cdot m\cdot\Delta t \tag{6}$$

In the formula: c is the specific heat capacity; for the quality; m is the Δt is temperature difference.

During the rotation of the idler, most of the heat generated by the rotation of the bearing Q is absorbed by the grease. It can be roughly assumed that the heat generated by the rotation of the bearing is equal to the amount of heat absorbed by the grease Q_1:

$$Q_1 = Q \tag{7}$$

The formula (5), (6), (7) combined available：

$$\Delta t = \frac{1.491\times10^{-10} f_0 \nu^{\frac{2}{3}} n^{\frac{5}{3}} d_m^3 + 1.05\times10^{-4} f_1 p_1 d_m n}{cm} \tag{8}$$

Through the type (8) can be obtained under different speeds of the bearing temperature rise. At the same time by the grease should be below the dropping temperature 20 ℃ -30 ℃ temperature conditions, you can calculate the bearing a maximum critical speed, to provide some reference for designers.

2.2 Labyrinth seal viscous resistance moment

Labyrinth seal is a non-contact seal, which can be divided into radial seal and axial seal, its rotation resistance is small, widely used in mining machinery, in view of this, the radial seal as an example for analysis.

When the roller adopts the radial sealing method, each section of the grease can be simplified as a separate sealing disk. Using the differential method, as shown in FIG. 1, a The tiny ring has an area of :, the angular velocity of the labyrinth seal is $dA = 2\pi\gamma d\gamma$, due to the labyrinth seal attached to the shaft, the angular velocity ω is zero.

Shear stress is:

$$\tau = \mu\omega\gamma / h \tag{9}$$

In the formula: ω is the labyrinth-type seal ring angular velocity; h is the labyrinth-type seal within the oil film thickness; μ is the dynamic viscosity of the fluid; γ is the labyrinth-shaped seal between the inner and outer oil film formed at any point radius.

Shear force is:

$$dF = \tau dA \tag{10}$$

Labyrinth ring viscous resistance moment:

$$dM_3 = \gamma dF \tag{11}$$

Integral to the above formula:

$$M_3 = \frac{\pi\omega\mu\left(\gamma_2^{\ 4} - \gamma_1^{\ 4}\right)}{2h} \tag{12}$$

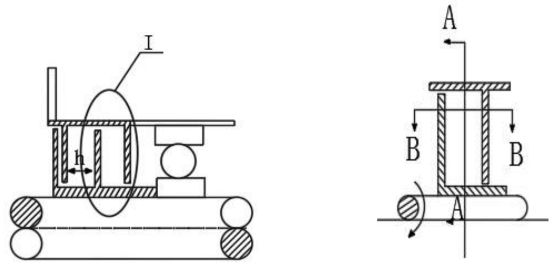
In the formula:

γ_2 is Outer diameter of the labyrinth seal; γ_1 is the inner diameter of the labyrinth seal.

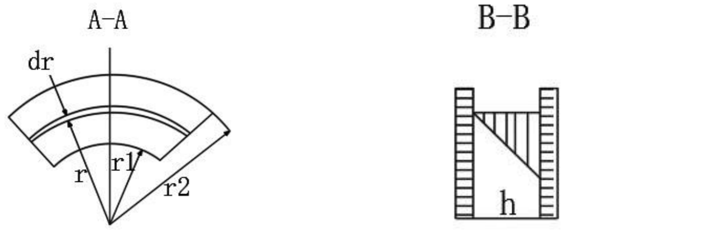
Set type labyrinth seal is formed between inside and outside the oil film thickness and were of equal h .A roller with two of the same type labyrinth seal, install it at the two ends of the roller, the total viscous drag torque for the labyrinth:

$$M_4 = \frac{z\pi\omega\mu\left(\gamma_2^{\ 4} - \gamma_1^{\ 4}\right)}{h} \tag{13}$$

In the formula: z is the number of oil film。



(a)Labyrinth ring assembly drawing (b) Ⅰ place local figure



(c) A section view (d) B to the cross-sectional view

Fig1 Maze seal within the film shear resistance moment calculation diagram

2.3 Rotary resistance torque generated by inner and outer seals

When calculating the rotation resistance generated by the inner and outer rings, the empirical formula proposed by SKF [2]

$$M_{seal} = K_{s1} d_s^{\ \beta} + K_{s2} \tag{14}$$

In the formula: M_{seal} is the friction moment of the seal ring; K_{s1} is a constant depending on the type of bearing; K_{s2} is a constant determined by the bearing type and seal; d_s is the diameter of the bearing shoulder; β is an index depending on the type of bearing and the seal.

3. Analysis of the rotational resistance torque of roller

3.1 Calculating formula of roller rotation resistance moment

$$\begin{aligned} T &= M + M_4 + M_{seal} \\ &= 1.42\times10^{-6} f_0(\nu\cdot \mathrm{n})^{\frac{2}{3}}\cdot d_m{}^3 + f_1 p_1 d_m \\ &+ K_{S1} d_s{}^{\beta} + K_{s2} + \frac{z\mu\pi\omega\left(r_2{}^4 - r_1{}^4\right)}{h} \end{aligned} \tag{15}$$

The relationship between speed n and angular velocity ω is:

$$\omega = 2\pi\cdot n \tag{16}$$

Substituting equation (16) into equation (15) yields:

$$\begin{aligned} T &= 1.42\times10^{-6} f_0(\nu\cdot \mathrm{n})^{\frac{2}{3}}\cdot d_m{}^3 + f_1 p_1 d_m + K_{S1} d_s{}^{\beta} \\ &+ K_{s2} + \frac{2n\mu\pi^2 z\left(r_2{}^4 - r_1{}^4\right)}{h} \end{aligned} \tag{17}$$

By (17) can be seen, when the forming roller in the specific operating conditions, ν, f_1, f_0, d_m, K_{s1}, K_{s2}, d_s, β, h, z, γ_2, γ_1, μ is the determined value, roller rotation resistance only by the roller speed and load impact.

Table 1 The main parameters

Name	Parameter
Kinematic viscosity of grease ν (mm^2/s)	68
Bearing inner diameter d (mm)	25
The outer diameter of the bearing D (mm)	52
Bearing load factor f_1	0.0011
Bearing structure and grease-related factors f_0	2.5
Index based on bearings and seals β	2.25
Bearing shoulder diameter d_s (mm)	28
Constant according to bearings and seals K_{s2}	0.0003
Constant according to bearing type K_{s1}	0.00181
The thickness of the film h (mm)	5
The number of oil film z	2
Labyrinth type outer and inner sealing piece diameter γ_2 (mm)	22.7
Labyrinth inside and outside the seal diameter γ_1 (mm)	13
Dynamic viscosity of grease μ $(pa\cdot s)$	0.0605

Take the idler roller (108 * 465) as an example, the bearing adopts the deep groove ball bearing (6205-2Z), and further analyzes the relationship between the rotational resistance torque of the idler roller and the speed and load. The main parameters are shown in Table 1.

Using Matlab software to draw the roller torque resistance and roller speed and load diagram.

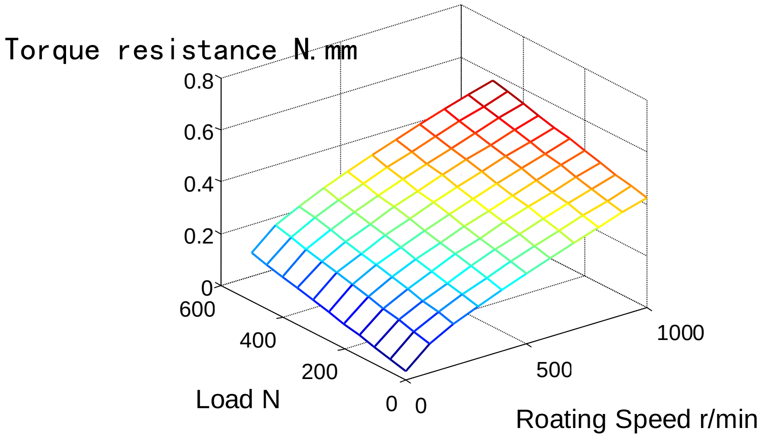


Fig 2 Rotational resistance torque and load and roller speed three-dimensional map

Through simulation we can get the following conclusions:

1. When the roller speed is constant, the rotational resistance torque increases with the increase of load; when the load is constant, the rotational resistance torque increases nonlinearly as the roller speed increases.

2. The rotating resistance moment increases with the load increases, but the increase is not large, which shows that in the actual operation of the idler roller, the belt load on the roller torque resistance has little effect.

3. The speed of 0 to 180, the slope of the curve is large, with the speed continues to increase, the slope becomes more and more gentle, which shows that in actual conditions, roller speed 0 to 180 in this When the interval is increased, the rotational resistance torque of the roller will increase rapidly, and the influence of the rotational speed on the rotational resistance moment of the roller will decrease gradually.

4. Conclusion

Through the analysis of the rotational resistance torque of the roller, the objective law of the rotational resistance torque of the roller under the influence of the roller speed and load is obtained. In order to further improve the quality of the roller and reduce the rotation resistance of the roller, MC type nylon roller can be considered to replace the traditional metal roller or roller to apply the magnetic suspension bearing and the magnetic fluid seal, finally achieving energy saving purpose.

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