

Parameters Calculation and Structure Design of Pipe Belt Conveyor

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Abstract

Pipe belt conveyor is a new type of special belt conveyor and it is widely used in conveying powder material. In the paper, the advantages of pipe belt conveyor are introduced. Calculation of pipe belt conveyor's main parameters is different from that of conventional belt conveyor's. The parameters such as throughput, belt speed, belt width, resistance, tension in belt and power are described. The length of transition section is analyzed because it is important to the belt life. Hexagon supporting rollers and tipping device are necessary parts of pipe belt conveyor. The structures of them are also discussed.

Keywords: Pipe Belt Conveyor, Transition Section, Hexagon Supporting Rollers, Tipping Device

1. Introduction

Pipe belt conveyor is a new type of special belt conveyor which developed from the conventional belt conveyor. In this conveyor, flat belt is forced to be tubular by supporting roller groups and material conveyed is enveloped in it. Therefore airproof conveyance is realized in whole conveyance line. Pipe belt conveyor was proposed in 1964 by Japan Pipe Conveyor (JPC), and it went into real use in 1979^[1]. After that, it was rapidly developed in Germany and America and widely used abroad. But it is not deeply studied and its' use is much limited in China.

2. The characteristics of pipe belt conveyor

Figure 1 is for the structure of pipe belt conveyor. The load is putted on by the feeder at the end of conveyor.

The belt is flat when it runs through the driven roller and it is conducted by a series of supporting rollers to be tubular gradually. Thus airproof conveyance is realized. In order to discharge, the pipe is also conducted by a series of supporting rollers to be flat near the driving roller. The conveyor discharges at its head. Two-way conveyance can be realized. But tipping device for belt must be added. Characteristics are obvious due to its

special structure comparing with other belt conveyor^[1].

(1) Unpolluted conveyance

In pipe belt conveyor, material doesn't come out and isn't influenced by environment because the belt is tubular and the two sides lap over each other. When it conveys powder, food and chemical material etc., this advantage is obvious.

(2) Big obliquity of conveyance

Obliquity can reach about 18° in the conventional belt conveyor. But in pipe belt conveyor, material is enveloped in pipe and friction between material and belt is greater than before. So obliquity can be increased to 30°. The bigger obliquity is, the shorter conveyance length will be. This can result in lower cost.

(3) Two-way conveyance is convenient

Belt can be tubular in return of pipe belt conveyor and material can be conveyed in the reverse direction by special device such as special feeder and tipping device.

(4) Conveyor bed is narrow

In conveyance, bed is narrow because the cross section is a circle. The required building space and building steel are reduced. The bed cost is low and it can be used when space is limited.

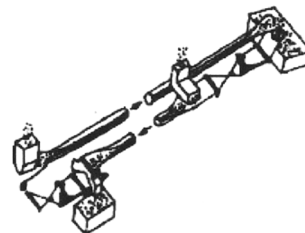


Figure 1. Structure of pipe belt conveyor

3. Main parameters calculation of pipe belt conveyor

Main parameters in pipe belt conveyor are throughput, belt width, belt speed and power. But production throughput is always given.

3.1 Calculation throughput

Throughput of conveyor can be formulated as

follow^[2]:

$$Q = 3600VF\gamma\phi$$

Where V is belt speed, F is the pipe area, γ is density of material conveyed and ϕ is coefficient of material filling, $\phi = 0.44 \sim 0.8$. If material size is less than one third of pipe diameter, $\phi = 0.8$. If material size is one third of pipe diameter, $\phi = 0.75$. If material size is half of pipe diameter, $\phi = 0.58$. If material size is two thirds of pipe diameter, $\phi = 0.44$.

3.2 Belt speed

Belt speed is determined by characteristic of material, throughput, belt width and the installation method of conveyor. Generally speaking, quick belt speed is beneficial because it can reduce belt width and tension in belt when throughput is constant. This will economize on investment in belt and power consumption. Belt speed usually used is $2 \sim 5$ m/s^[3].

3.3 Belt width

Belt width can be calculated according throughput. The belt diameter can be expressed^[2]:

$$d = \sqrt{\frac{41400V\gamma\phi}{\pi}}$$

Where d is pipe diameter.

The lap of two sides is about one third or half of pipe diameter. When belt is tubular, the relationship between belt width and pipe diameter is as follow:

$$B = (\pi + (1/3 \sim 1/2))d$$

3.4 Running resistance calculation

The method has no difference in resistance calculation between pipe belt conveyor and conventional belt conveyor. Generally, Coefficient of resistance is usually used in resistance calculation. Tension in belt is calculated point by point. Extrusion force is increased because material is enveloped in pipe. Therefore coefficient of resistance in pipe belt conveyor is greater than that in conventional belt conveyor.

(1) Resistance in tangent

Resistance in belt with load^[2]:

$$W = (q_0 + q_1 + q_2) \omega gl \cos \beta \pm (q_0 + q_1) Hg$$

Resistance in belt without load:

$$W = (q_0 + q_3) \omega gl \cos \beta \mp q_0 Hg$$

Where W is resistance in running, q_0 is the unit mass of belt per meter, q_2 is the average unit mass of the upper supporting rollers per meter along the belt, q_1 is the unit mass of material per meter along the belt, q_3 is the average unit mass of the below supporting rollers

per meter along the belt, l is the length of conveyance, β is obliquity of conveyance and ω is coefficient of resistance in supporting rollers, showed in table 1.

Table 1. Coefficient of resistance in supporting rollers

condition	parallel supporting rollers	trough supporting rollers	hexagon supporting rollers
clean, dry and no wearing dust indoors	0.018	0.02	0.035~0.045
few wearing dust under normal temperature	0.025	0.03	0.045~0.055
lots of wearing dust outdoors	0.035	0.04	0.055~0.075

(2) Resistance in curvature

Resistance in curvature is caused by belt ossification and friction in roller bearings. It is proportional to the tension at curvature entrance. That is^[2]:

$$S_i = CS_{i-1}$$

Where S_i is the tension in belt at curvature exit, S_{i-1} is the tension in belt at curvature entrance and C is coefficient of resistance.

3.5 Tension calculation in belt

After resistance in each section has been calculated, we can calculate the tension at every point. We can divide whole path into several tangents and curvatures and number every joint before we calculate.

Tension at any point is calculated by the formula as followed^[2]:

$$S_i = S_{i-1} + W_{(i-1) \sim i}$$

Where S_i and S_{i-1} are tension in belt at point i and point $(i-1)$, $W_{(i-1) \sim i}$ is resistance between point i and point $(i-1)$.

The tension at driving roller entrance and driving roller exit can be obtained. Circumferential force on driving roller can be described by following expression:

$$P = S_n - S_1$$

Where P is circumferential force on driving roller, S_n is the tension in belt at driving roller entrance and S_1 is the tension in belt at driving roller exit.

The following condition must be satisfied because the belt do not permitted to slide on driving roller^[2].

$$S_n \leq S_1 e^{\mu\alpha}$$

Where μ is the coefficient of friction between the belt

and driving roller, α is angle of the belt enveloping on the roller.

3.6 Power calculation

Power is mainly consumed in overcoming running resistance. And some power is used in elevating material in sloping conveyor. Power on driving roller shaft can be calculated by the follower expression^[2]:

$$N_0 = \frac{PV}{1000}$$

So the motor power is:

$$N = \frac{KN_0}{\eta}$$

Where K is a factor of safety and η is transmission device efficiency.

4. Structure design of pipe belt conveyor

4.1 The length of transition section

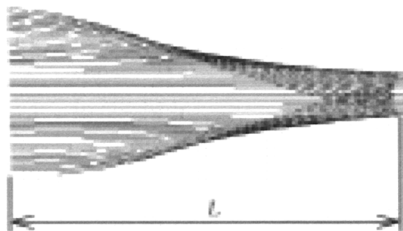


图3 过渡段长度 L

Figure 2. Length of transition section

Transition section is shown in figure 2. The belt is flat at driving roller and driven roller. The belt is turned from flat belt into tubular one at transition section. The length of transition depends on the permissible extension of belt. If transition section is too short, additional deformation and stress will be great in both sides of belt. This will result damage to belt. If transition section is too long, distance of airproof conveyance in whole line will be shortened. Generally speaking, the length of transition section equals to 25 diameters in nylon belt while 50 diameters in wire rope belt^[3].

4.2 Design of supporting rollers

Parallel supporting rollers must be used near driving roller and driven roller so that the angle of the belt enveloping on the roller is big enough. But at other position in transition section trough supporting rollers are used. Thus the flat belt can become tubular one gradually and additional stress at edge of belt can be reduced. So trough angle is usually $20^\circ, 30^\circ, 45^\circ, 60^\circ$ and 90° . Since impact load at

material entrance is inevitable, three groups of cushioning supporting rollers can sever to reduce the intensity of shock loads and its' spacing is about 300~500mm^[4].

Hexagon supporting rollers are widely used after the flat belt becomes tubular one^[5]. Rollers can be equipped on the same side or two sides of the supporting board. It is easy to positioning rollers precisely and the force in belt is uniform when the six rollers are equipped on the same side of supporting board. Generally speaking, the adjacent rollers spacing should not exceed the belt thickness, usually 4~8mm. If the spacing were too big, the edge of belt would jam in it. There are three rollers on each side of the supporting board when rollers are equipped on two sides of it. The length of roller can be longer than the length of hexagon side and the belt can not jam in the space of adjacent rollers. On the other hand, the force in supporting board is uniform. Rollers on supporting board are shown in fig.3 and fig.4.

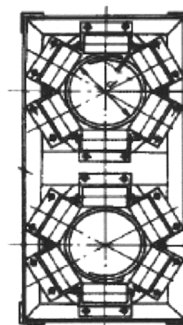


Figure 3. Rollers on same side of supporting board

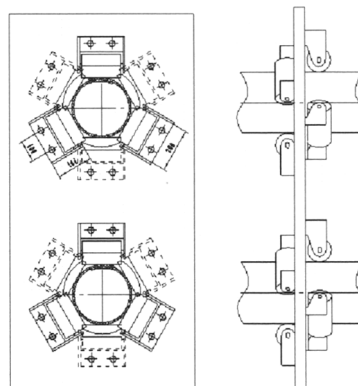


Figure 4. Rollers on two sides of supporting board

Rigidity is greatly increased after flat belt becomes tubular. So supporting rollers spacing can also be increased. Supporting roller groups spacing with load is about 1.2m or 1.0m and it is 3.0m in return in conventional conveyor, while it varies with the pipe diameter in pipe belt conveyor. The greater pipe diameter is, the greater the spacing is^[5]. The relationship

etween pipe diameter and the spacing is shown in table 2^[5].

Table 2. The relationship between pipe diameter and supporting roller groups spacing

pipe diameter(mm)	ϕ 150	ϕ 200	ϕ 300	ϕ 450
supporting roller groups spacing(m)	1.5	1.6	1.8	2.7

4.3 Belt tipping device

Remnant material on belt will pollute environment and adhere to rollers and supporting rollers after discharge. This will result to belt wear. So the same side of belt is always used when conveying material. Belt tipping device severs to overturn the belt ^[6]. It consists of several rollers. The belt is hold by two horizontal rollers and two vertical rollers and turn 90° . Then another two horizontal rollers hold the belt and turn it 90° at the same direction. Thus belt overturn is realized. The spacing between horizontal rollers and vertical rollers depends on belt width and operation conditions.

5. Conclusion

Compared with conventional belt conveyor, pipe belt conveyor has so many advantages that it will be widely used in the future. When calculating parameters, some

formals in convention belt conveyor can be used in pipe belt conveyor, but some coefficients must be modified. The power is greater in pipe belt conveyor than in conventional belt conveyor because friction is great in pipe belt conveyor. The transition section length depends on the belt type and pipe diameter. Parallel supporting rollers and trough supporting rollers in conventional belt conveyor can also be used in pipe belt conveyor, but trough angle varies with the poison where trough supporting rollers are installed. Hexagon supporting rollers and tipping device exist only in pipe belt conveyor and their structure is described in this paper. Supporting roller groups spacing also varies with pipe diameter.

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