CHANGES OF ROLLING FRICTION LINK CHAIN STEP IN LINK TURNING

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Abstract. The article describes theoretical research in chain step changes of dismountable conveyor plate chains with rolling friction links.

Key words: chain step, chain step change, conveyor chain, rolling friction links.

Introduction

Installation of a rolling friction link in the conveyor chain allows to essentially increase the lifetime of the chain [1] and it is a progressive method in construction of fast wearing links. In order to construct a chain with rolling friction links able to operate it was necessary to investigate theoretically the chain step changes in the process of mesh with the sprocket. Figures 1 and 2 show the process of the chain step change. Let us explain the reasons for the chain step change. The chain step t_1 is the distance between the centres of the proximal axles.

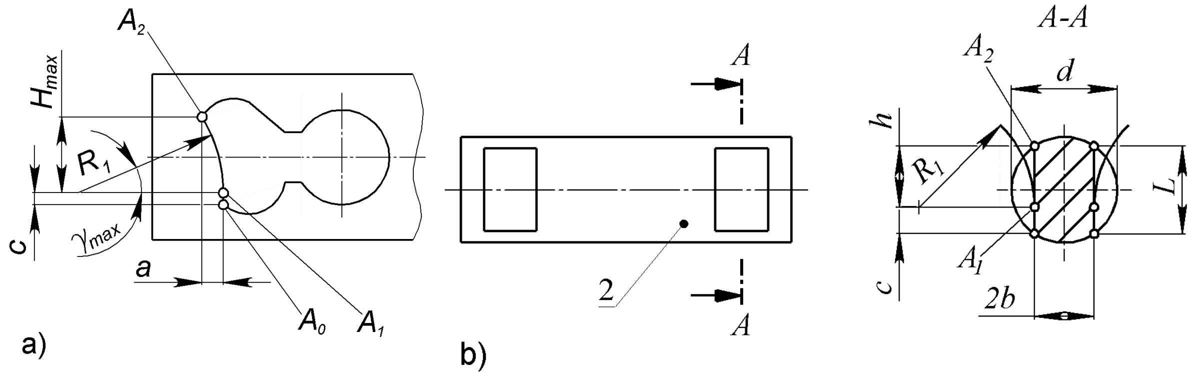

Fig. 1. **Characteristic dimensions of rolling friction link:** a – plate; b – axle

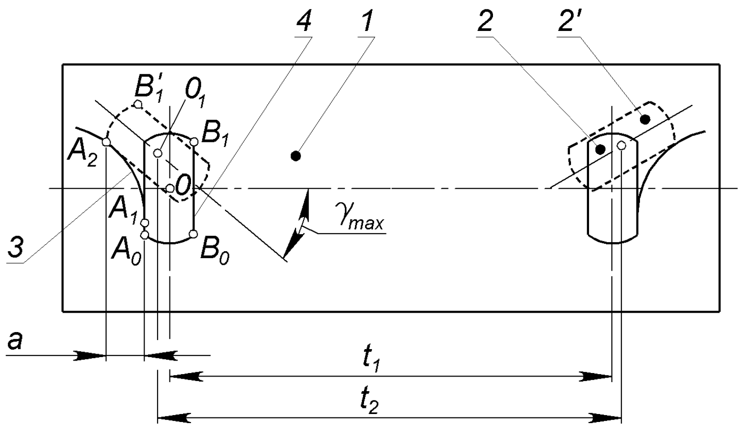

Fig. 2. **Scheme of rolling link operation:** 1 – plate; 2 – axle; 2' – axle position after turning in angle γ_{max}; 3 – plate operation contact line (support surface); 4 – axle plane

The length of the axle plane operation surface (Figure 1, b)

$$L = \sqrt{d^2 - 4b^2}\ , \tag{1}$$

where d – axle diameter;
b – axle “neck” (rectangle shorter edge) width side.

The necessary rolling distance length (arc) of the plate arcuate operation surface that corresponds to the axle plane length:

$$h = L - c \,, \tag{2}$$

where c – length of axle and plate support surface straight part area.

The maximal turning angle of every plate in the chain gearing process:

$$\gamma_{\max} = \frac{180^\circ m}{z} \,, \tag{3}$$

where m – number of sprocket steps;
z – number of sprocket teeth.

The total turning angle of the chain links:

$$\gamma_{\Sigma} = \frac{360^\circ m}{z} \,. \tag{4}$$

The necessary bending radius of the operation part of the plate:

$$R_1 = 57.3 \frac{h}{\gamma_{\max}} \,. \tag{5}$$

The distance between the part rolling starting and final points (Fig. 1, a; Fig. 2):

$$a = H_{\max} tg \frac{\gamma_{\max}}{2} = R_1 (1 - \cos \gamma_{\max}) \,, \tag{6}$$

where $H_{\max} = R_1 \sin \gamma_{\max}$ – maximal height of rolling (axle and plate point A_2 coincide) (Figure 1, a).

As it can be seen in Figure 2 the link chain step changes ($\Delta t = t_2 - t_1$) with the chain links getting in and out of mesh with the chain sprocket and it depends on the angle γ, i.e., on the number of the sprocket teeth. It occurs when the axle plates are rolling along the cylindrical operation surface of the plate.

The chain step change should be considered organising the chain mesh with the sprocket teeth; it also influences the wear of the operation surfaces of the chain parts and sprocket teeth.

Materials and methods

Further we will specify the chain step change methods. Kinetic scheme of a rolling link of one-sided chain link turning is shown in Figure 3. It depicts a case when with the plate turning along the convex operation surface of the plate (radius R_1) the straight operation surface of the axle is rolling ($R_2 = 0$).

According to the scheme (Figure 3.)

$$\cup A_1 A_2' = A_1 A_2 = A_1' A_2' = R_1 \gamma \,, \tag{7}$$

where R_1 – plate operation surface radius;
γ – axle turning angle.

The chain step t change:

$$\Delta t = 2(R_1 + b - R_1 \cos \gamma - l) \,. \tag{8}$$

The plate operation surface radius R_1 and a half of the axle cross-section size b is determined by the kinematic and strength calculation. The size l is expressed as follows:

$$l = 0_1' A_2' \cos \gamma_1 \,,$$

where $\gamma_1 = \gamma - (90^\circ - \delta) = 90^\circ - \delta - \gamma$.

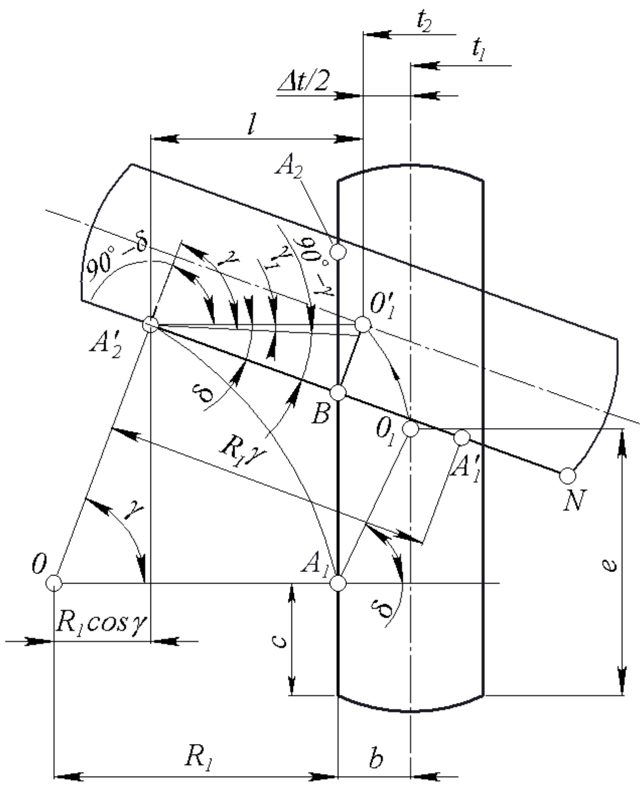

Fig. 3. **Kinetic scheme of chain link with one sided link turning operation and change of step**

Thus:

$$|l| = \sqrt{(R_1\gamma + c - e)^2 + b^2} \cdot \cos(90^\circ - \delta - \gamma). \tag{9}$$

The angle δ:

$$\delta = \operatorname{arctg}\frac{b}{R_1\gamma + c - e}, \tag{10}$$

where c – length of the axle flat operation surface that carries the load during the chain straightforward movement (determined calculating in contact strength);
e – half of the axle flat operation surface length L, that depends on the turning angle γ_{max}.

Inserting the correlation (9) in the expression (8) after transformation we get:

$$\Delta t = 2\left[R_1 + b - \sqrt{R_1^{\,2}\gamma^2 + b^2} \cdot \cos(\delta - \gamma) - R_1\cos\gamma\right]. \tag{11}$$

It should be considered if the angle is given $\gamma = \gamma_{max} = 180^\circ\, m/z$, then $e = R_1\gamma_{max}$.

If e is given , then $\gamma_{max} = \dfrac{e}{R_1}$.

Example.

Given:

- number of sprocket steps $m = 2$;
- number of sprocket teeth $z = 13$;
- length of axle flat operation surface $c = 2$ mm;
- axle cross-section size $b = 5$ mm;

- half of axle flat operation surface length e = 7.5 mm;
- plate maximal turning angle $\gamma_{\max} = 180^{\circ}\frac{m}{z} = 180^{\circ}\frac{2}{13} = 27.69^{\circ}$;
- plate operation surface radius $R_1 = \frac{[57.3(L-c)]}{\gamma_{\max}} = \frac{57.3(15-2)}{27.69} = 26.9$ mm.

Size $L - c = h$ – necessary length of the axle rolling surface.

The chain step Δt change depending on the plate turning angle γ is calculated. The calculation results are summarised in Table 1.

Table 1

Chain step change Δt, mm

Turning angle γ,°	0	5	10	15	20	25	27.69
Δt	0	0.79	1.24	1.37	1.18	0.70	0.34

Knowing the values d and b the operation flat surface length L is calculated according to (1).

Results and discussion

The article describes the contact of parts between the plate (of the axle) and surface profiled by the radius (of the plate).

The chain step change negatively influences the mesh of the chain and the sprocket as well as promotes lengthening of the chain step in the process of wearing and wearing of the sprocket teeth.

As the number of the chain sprocket teeth is not large and due to this the step change can be considerable, the size of the axle and plate operation surfaces (not the arc) should be such that the chain step change is within the permissible limit (chain step allowance range).

In compliance with the chain standard ГОСТ 588-81 the allowance for the chain step (0.001…0.004)t is determined. For example, if the chain step is 125 mm, the allowance is 0.0036t = 0.0036·125 = 0.45 mm. Usually the step allowance is assumed to be $t^{+0.01t}_{-0.004t}$, that corresponds to the chain with a step $125^{+0.4}_{-0.6}$.

The conveyer ТСН– 3.0Б plate chain step allowance is determined $125^{+0.4}_{-0.2}$.

The permissible difference of sprocket teeth steps if the arc speed $v < 3$ m·s^{-1}, at the second precision class (ГОСТ 592-75):

$$\delta = 0.025\sqrt{t\frac{z}{m}} = 0.025\sqrt{125\frac{13}{2}} = 0.7 \text{ mm.} \tag{12}$$

Up-dating of the chain construction is related to the change of the shape of the axle operating surface. Instead of the plates (Figures 1-3) radius form hollows are used [2-4]. Contact of the convex and concave surfaces improves the rolling process and decreases contact tension. Such kinds of rolling links still have to be researched in.

Conclusions

The study revealed:

1. If $c = e$, then Δt = – 0.074; –2.24 mm, i.e., the chain step only shortens.
2. In some cases the chain step increases as well as decreases. For example, if m = 3, z = 20, e = 7.5 mm, b = 5 mm, c = 4.5 mm and R_1 = 22.28 mm, then at the beginning the chain step increases, (Δt = 0.16; 0.5; 0.2 mm), but at the final stage of the turning starts to decrease (Δt = – 0.43; – 0.86 mm).

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