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ANALYSIS THE PHENOMENON OF QUEEZING SOIL IN PROCESS WORKING OF CHAIN TRENCHERE

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Abstract: *Analysis the process conveyance cutting soil from digging trench of chain trencher has been developed. The performance of a chain trencher is expressed by its production (excavation) rate. The production rate, i.e, the volume of soil excavated per hour, affects the time necessary to excavate a trench.Several factors affect operation efficiency of chain trencher. One of these factors is the phenomenon of squeezing soil in process conveyance cutting soil of chain trencher.*

This paper deals with theoretical study of the phenomenon of squeezing soil in process working of chain trenching machine, relationship between volume accumulated soil cuttings and volume available for one complete interval between tracking teeth and use it to lay out the cutting teeth on cutting assembly of Russian digging machine PZM-2 so that to ovoid the phenomenon of squeezing soil.

Keywords: *chain trenching machine, performance, phenomenon of squeezing soil*

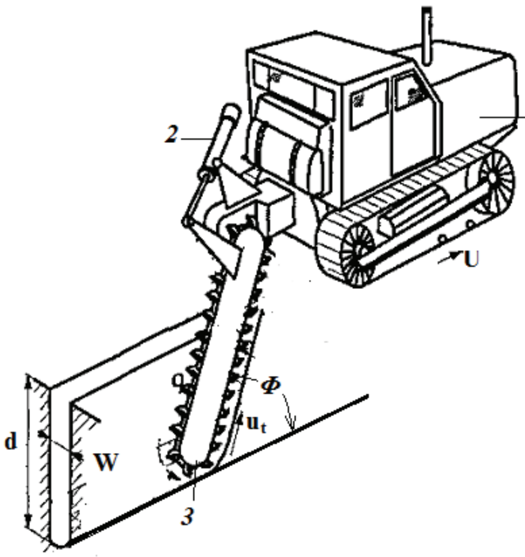
INTRODUCTION

Chain trencher is a machine that uses a rotating cutting chain equipped with teeth to excavate trenches for underground cables and pipelines. When a chain trencher's digging a trench, its teeth produce cuttings throughout theirs working sweep, and the working chain is almost used as a conveyor to remove accumulated soil cuttings simultaneously. The rate accumulated soil cuttings by the teeth may be more, equivalent or less than a conveyant capablity of working chain. When rate accumulated soil cuttings by the teeth is equivalent or more than a conveyant capability of working chain, the accumulated soil cuttings begins to squeeze, harden and causes difficulty to clear it. The soil remains on the chain, comes back to the working face and the consequences of that cause reduction in productivity of chain trencher. This situation is called phenomenon of queezing soil.

EXPOSITION

Chain trenching machine and its cutting assembly

The cutting assembly on a chain trencher machine (Fig.1) usually consists of a maneuverable cantilever support member that carries the working chain and its guides. The endless chain carries cutting teeth to cut the soil from working surface. The cutting tools on endless chain are laid out in a repeating pattern that is symmetrical about the center line of the chain face. The free end cutting assembly is known as the nose. The nose is usually the trailing end of the cutting assembly. The sprocket at the nose, which normally is not driven, is the nose sprocket [Mellor, M. (1976)].



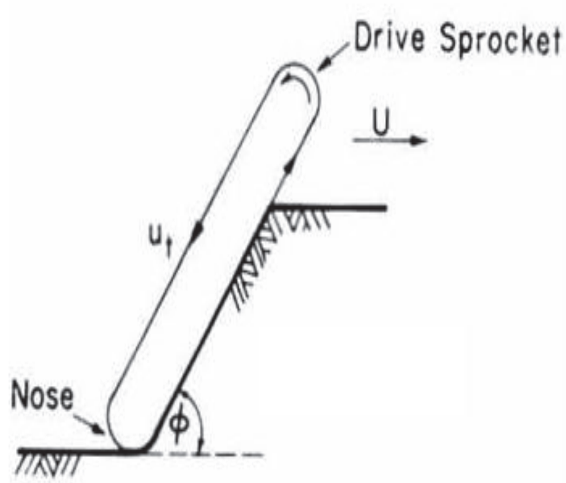


Fig.1. Chain trenching machine and it's cutting assembly:
1 – truck carrier; 2 – hydraulic cylinder; 3 – cutting assembly; d – cutting depth;
W – cutting wide; Φ – cutting angle; u_t – tangential tooth speed; U – traverse speed.

When chain trencher machine is trenching, the machine is normally operated with the drive sprocket clear of the work and rotating so as to pull the active side of the working chain towards itself in tension. The chain tends to convey cuttings to the free surface, and to pull the cutting assembly into the work surface. The angle *Φ*, can vary by the hydraulic cylinder 2, but it is commonly less than 90^0 [Utinov A.B. (2007)].

Chipping depth

When a chain of chain trenching machine is cutting soil under typical conditions, as in Figure 2, each tooth enters the work face at point A with a cutting depth h^{AB} that is close to zero; transient values of h^{AB} then increases steadily through the curved portion of the nose AB, until it reaches the steady maximum value cutting depth h that will be maintained throughout the rest of working sweep to the free surface [Homelite. (1979)].

The transient values of h^{AB} can be determined:

$$h^{AB} = \frac{U}{u_t} S \sin\theta \tag{1}$$

When the swept angle of the nose sprocket θ reaches the exit cutting angle *Φ*. h^{AB} reaches its maximum value h .

Deriving the value of h directly from consideration of the motion of the straight part of the cutting assembly, it can be seen that cutting depth h is determined by the forward movement of the machine at speed U during the time interval Δ_t between successive tooth passes through a given horizon such as C-C' in Figure 2. If the tangential tool speed is u_t and the lineal spacing between tracking cutters is S, then $\Delta_t = S/u_t$. In this same time interval of the traverse motion gives the whole cutting assembly a horizontal displacement of $(U\Delta_t)$, so that the horizontal penetration of the tooth is (SU/u_t). The theoretical cutting depth h, which here is taken to be cutting penetration normal to the face of the working chain, is thus

$$h = \frac{U}{u_t} S. sin\emptyset \tag{2}$$

Which is identical to the limit value of eq 1. Equation 2 is shown graphically in Figure 3 for typical values of U/u_t.

For a chain trenching machine operating at set values of U, u_t and S, cutting depth as a function of cutting angle Φ and the theoretical maximum cutting depth h_{max} occurs with cutting angle $\Phi = 90^0$:

$$h_{\max} = \frac{U}{u_t} S \sin\phi_{\max} = \frac{U}{u_t} S \sin 90^0 = \frac{U}{u_t} S, \tag{3}$$

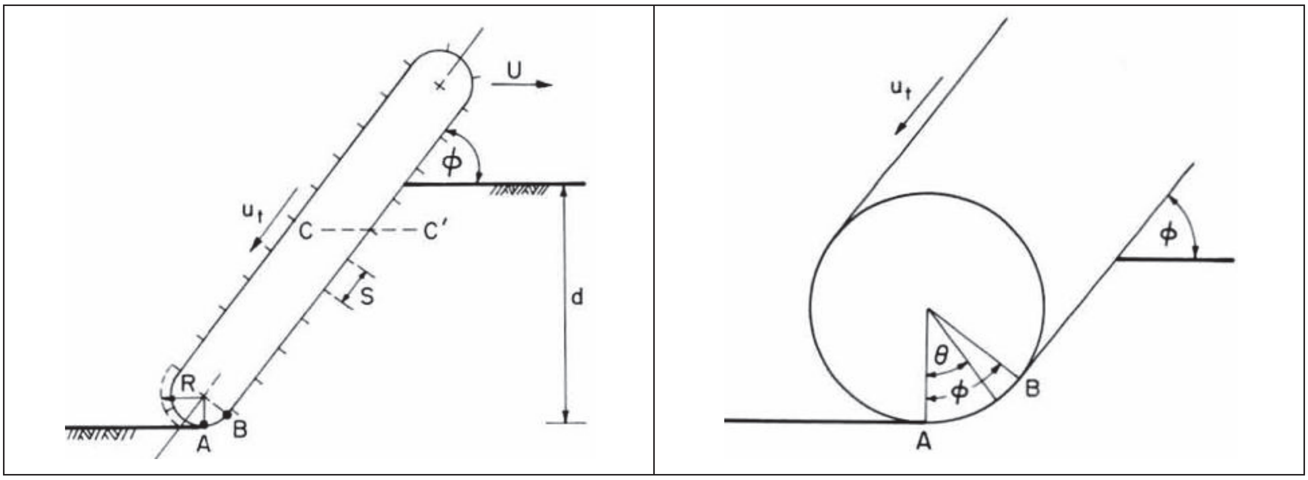


Fig.2. Symbols used in working chain analysis:
S – longitunal tooth spacing; R – nose radius

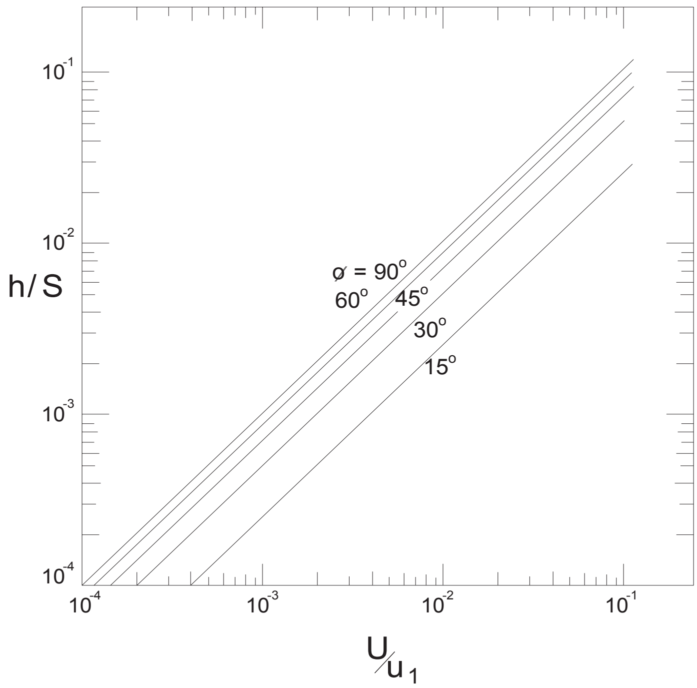


Fig.3. Plot showing cutting depth h as a functionof tangential tooth speed u_t, traverse speed U, longitunal tooth spacing S and cutting angle Φ

Performance of cutting

Processes cut by teeth and conveyed by chain of chain trenching machine are co-occurrent. Each tooth produces cuttings throughout its working sweep, and the working chain is almost invariably used as a conveyor to remove accumulated soil cuttings [Arkady N. Schipunov (2013)].

For unit width of the working chain, the approximate in-place volume of soil cut by one tooth at rounded nose of cutting assembly (v_n) can be obtained by integration of eq 1:

$$v_n = \int_0^{\theta \max} h^{AB} R d\theta = RS \frac{U}{u_t} \int_0^{\theta \max} \sin\theta d\theta = RS \frac{U}{u_t}(1 - cos\emptyset) \tag{4}$$

The in-place volume of soil cut by one tooth along the straight section of the cutting chain (v_b) is

$$v_b = h\left[\frac{d}{sin\emptyset} - R(1 - cos\emptyset)\right] = \frac{RSU}{u_t}\left[\frac{d}{R} - sin\emptyset(1 - sin\emptyset)\right] \tag{5}$$

The total volume cut per unit width of cutting chain (v_c) is thus

$$v_c = v_n + v_b =$$

$$= \frac{RSU}{u_t}(1 - cos\emptyset) + \frac{RSU}{u_t}\left[\frac{d}{R} - sin\emptyset(1 - sin\emptyset)\right] =$$

$$= \frac{RSU}{u_t}(1 - cos\emptyset) + \frac{RSU}{u_t}\left[\frac{d}{R} - sin\emptyset(1 - sin\emptyset)\right] =$$

$$= \frac{SdU}{u_t}\left[1 - \frac{R}{d}sin\phi(1 + cos\emptyset - sin\phi)\right], \quad (6)$$

With a long cutting assembly and small nose radius

$$\frac{R}{d}sin\phi \ll 1 \text{ and } \frac{R}{d}cos\phi \ll 1 \quad (7)$$

And therefore

$$v_c = \frac{SdU}{u_t} \quad (8)$$

Marking K_b is a bulking factor, the actual volume of cutting $v_c^{'}$ from the in-place volume v_c is thus:

$$v_c^{'} = K_b v_c = K_b Sd\frac{U}{u_t}\left[1 - \frac{R}{d}\sin\phi\left(1 + \cos\phi - \sin\phi\right)\right] \quad (9)$$

Phenomenon of squeezing soil

Since the chain is acting as a conveyor, there must be sufficient space between the teeth (v_a) to store and transport the volume of actual volume of cutting ($v_c^{'}$). For one complete interval between tracking teeth the space available per unit width is

$$v_a = Sh_t - v_t \quad (10)$$

Where h_t is the height of the cutting tooth above the working chain surface and v_t is the volume of the tooth itself. If each tooth is represented in simplified form as a solid rectangular block of total height h_t and length s_t, then $v_t = s_t h_t$. More generally, an effective tooth length s_t could be defined as v_t/h_t, so that the space available for conveyance of the cuttings produced by one tooth in unit width of the belt can be expressed as

$$v_a = \left(S - s_t\right)h_t \quad (11)$$

The space available for cutting should be equal to, or greater than, the volume of loose cuttings produced in a working sweep, and therefore a design condition is

$$v_a \geq v_c^{'} \quad (12)$$

i.e.

$$\left(1 - \frac{s_t}{S}\right)\frac{h_t}{d} \geq K_b\frac{U}{u_t}\left[1 - \frac{R}{d}\sin\phi\left(1 + cos\phi\text{-}\sin\phi\right)\right] \quad (13)$$

or, with a long bar and small nose radius,

$$\left(1 - \frac{s_t}{S}\right)\frac{h_t}{d} \geq K_b\frac{U}{u_t} \quad (16)$$

Check design condition for adequate conveying of transforming Russian digging machine PZM-2

The original Russian digging machine PZM-2 is designed for digging trenches in mountain area where the soil conditions are dry and britle. In order to transform PZM-2 so that it can dig trenches in the red river delta with sticky clay or gumbo-type conditions, we replace the original bullet bits by flat cutting blades, and below is the checking condition for adequate conveying.

The transforming digging machine PZM-2 is intended for digging of trenche with wide W = 0,65 m; maximum depth d = 1,2 m. The cutting teeth are arranged with 5 cutting track and on every chain’s link, the length of one link 0,125 m. the height of the cutting tooth above the working chain surface h_t = 65 mm, thickness of the tooth s_t = 40 mm. The machine can make a single-pass traverse of a 3 m/min, chain speed and tooth speeds are the same with 2 value 240 m/min and 300 m/min.

Traverse speed U = 3 m/min; tangential tooth speed: u_t = 150 m/min and 240 m/min; with 5 cutting track, thelongitunal tooth spacing S = 0,125.5= 0,625 m, taking $\Phi = 70^0$.

- Thus with u_t = 150 m/min, the theoretical cutting depth h is:

$h = \frac{3}{150}0{,}625 sin70$= 0,01174 = 11,74 mm

- Thus with u_t = 240 m/min, the theoretical cutting depth h is:

$h = \frac{3}{240}0{,}625 sin70$ = 0.007341 m = 7,341 mm;

- The required design condition for adequate conveying is

$$\left(1-\frac{s_t}{S}\right)\frac{h_t}{d} \geq K_b\frac{U}{u_t}$$

$$\left(1-\frac{s_t}{S}\right)\frac{h_t}{d} = (1 - 40/625)65/1200 = 0{,}0507$$

$$K_b\frac{U}{u_t} = 2{,}6.3/240 = 0{,}052 \text{ (with } u_t = 150 \text{ m/min)}$$

$$K_b\frac{U}{u_t} = 2{,}6.3/240 = 0{,}0325 \text{ (with } u_t = 240 \text{ m/min)}$$

Bucking factor for clay K_b= 1.8 - 2.6

Thus: transforming digging machine PZM-2 is theoretically capable of clearing its cutting systematically with U =3m/min and u_t = 240 m/min and it isn't theoretically capable of clearing its cutting systematically with U =3m/min and u_t = 150 m/min.

CONCLUSION

This study has shown us that the chipping depth of a chain trenching machine is related to the tangential tooth speed u_t, the traverse speed U, the spacing between teeth S and the angle of the cutting assembly *Φ*.

If working length of the tooth is known, the maximum of traverse speed U can be determined by formul (3) and a consideration can be taken when designing or transforming a chain trenching machine.

Inequality (16) is actually oversimplified, it suffices to demonstrate the general design considerations to either adequate available space for conveying the cutting soil or not.

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