Analysis the Factors Affecting Conveyance Rate of Unbucket Chain Trenching Machine

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Abstract: *Analysis the process cutting soil 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. For a given conditions of digging soil, there are several factors affect performance rate of chain trenching machine relate to cutting depth of trench d; cutting wide of trench W, cutting angle Φ; longitunal tooth spacing S; tangential tooth speed u_t and traverse speed U. This paper deals with theoretical study the factors affecting conveyance rate 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 trenchingmachine, performance, conveyance rate.*

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 conveyantcapablity of working chain. When rate accumulated soil cuttings by the teeth is more than a conveyant capability of working chain, the accumulated soil cuttings begins to squeeze, harden and causesdifficulty to clear the soil. The soil remains on the chain, comes back to the working face and the consequences of that cause reduction 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 usually consists of a maneuverable cantilever support member that carries the working chain and its guides. The endless chain that 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 [1, 2, 5].

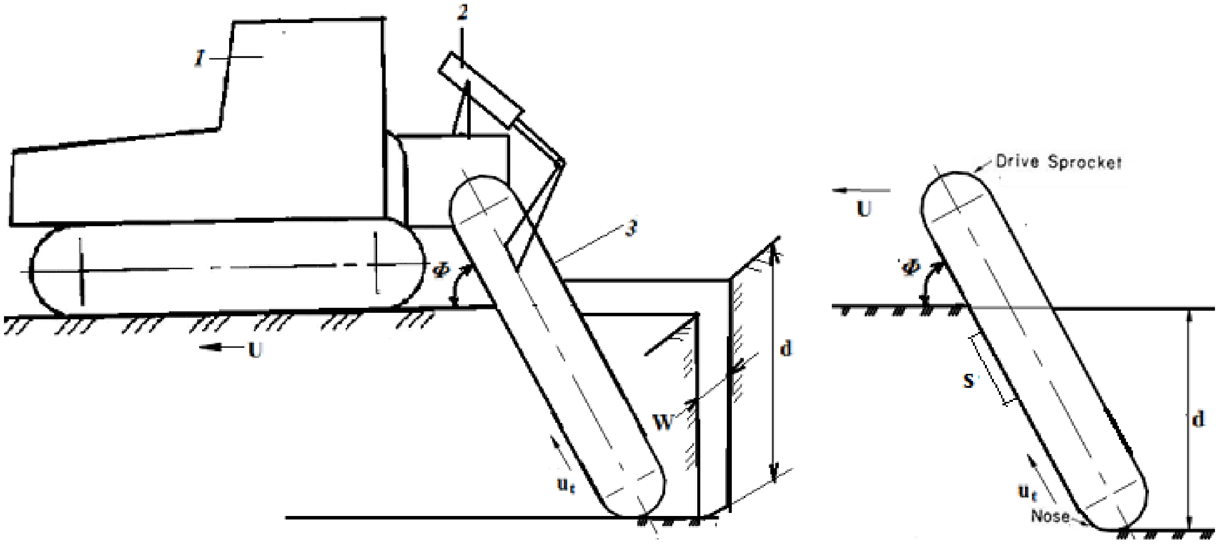
When chain trencher machine is trenching, the machine is normally operated with the drive sprocket clear of the work and rotating so as to pull the active side of the working chain towards itself in tension(Figure 1). The chain tends to convey cuttings to the free surface, and to pull the cutting assembly into the work surface. The angle Φ, can vary by the hydraulic cylinder 2, but it is commonly less than 90^0 [11]

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 [3].

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

$$h^{AB} = \frac{U}{u_t} S \sin\theta \quad (1)$$



a) **b)**

Fig. 1 a) chain trenching machine and b) cutting assembly

1 – truck carrier; 2 – hydraulic cylinder; 3 – cutting assembly; d – cutting depth; W – cutting wide; Φ - cutting angle; S – longitunal tooth spacing; ut - tangential tooth speed; U - traverse speed

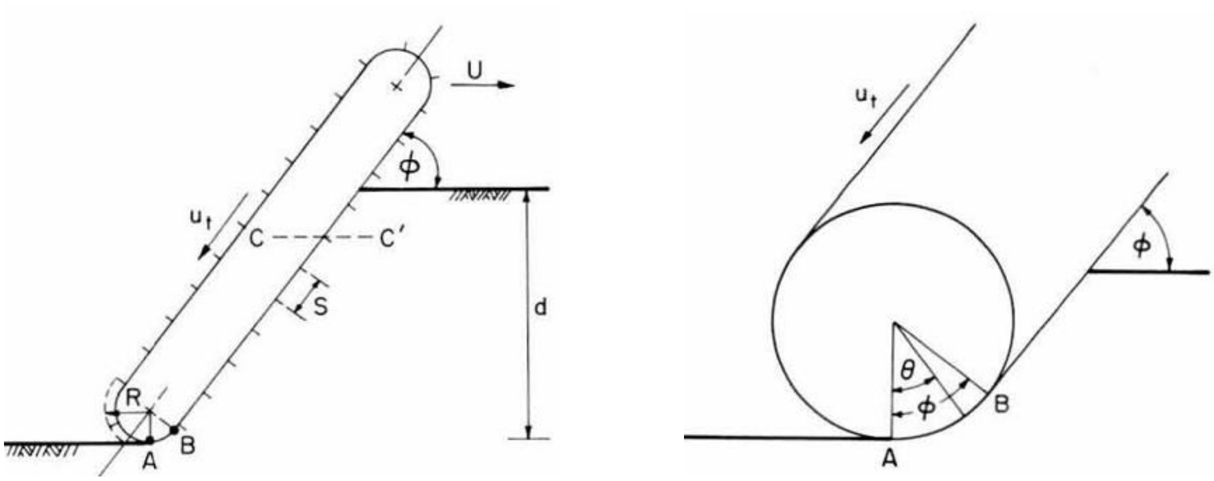


Fig. 2 Symbols used in working chain analysis:

S – longitunal tooth spacing; R – nose radius

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 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

$$h = \frac{U}{u_t} S.\sin\emptyset, \qquad (2)$$

Which is identical to the limit value of eq1. 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 $\Phi = 90^0$:

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

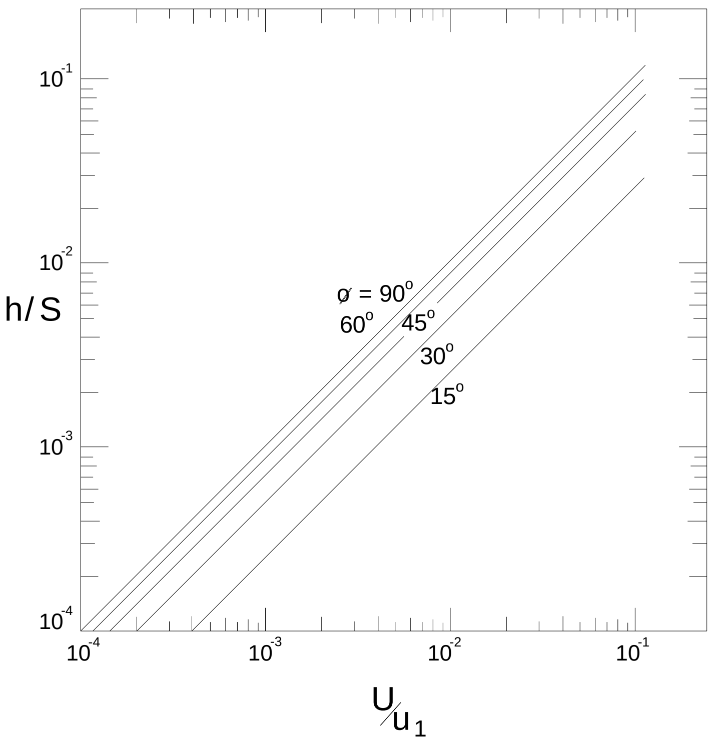


Fig. 3 Plot showing cutting depth h as a functionof tangential tooth speedut , traverse speed U, longitunal tooth spacing S and cutting angle Φ

PERFORMANCE OF CUTTING

Processes cutting by teeth and conveying 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.

For the width of the working chain W, the approximate in-place volume of soil cut by the chain at rounded nose of cutting assembly Q_n can be obtained by integration of eq 1:

$$Q_n = \int_0^{\theta\max} Wh^{AB} Rd\theta = RS\frac{U}{u_t}\int_0^{\theta\max} \sin\theta d\theta = WRS\frac{U}{u_t}(1-cos\emptyset), \quad (4)$$

For the width of the working chain W, the approximate in-place volume of soil cut by the chain at along the straight section of the cutting chain (Q_b) is

$$Q_b = Wh\left[\frac{d}{sin\emptyset} - R(1-cos\emptyset)\right] = \frac{WRSU}{u_t}\left[\frac{d}{R} - sin\emptyset(1-sin\emptyset)\right], \quad (5)$$

The total the approximate in-place volume of soil cut by the chain (Q_c) is thus

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

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

$$Q_c = \frac{WSdU}{u_t}, \quad (8)$$

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

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

ADEQUATE PROVISION TO AVOIDE PHENOMENON OF SQUEEZING SOIL

Since the chain is acting as a conveyor, there must be sufficient space in one complete interval between tracking teeth (Q_a) to store and transport the volume of actual volume of cutting ($Q_c^{'}$). For one complete interval between tracking teeth the space available of working chain with W width is

$$Q_a = WSh_t - Q_t \quad (10)$$

Whereh_t is the height of the cutting tooth above the working chain surface and Q_t is the volume of all the teeth theirselves of one complete interval. If the volume of all the teeth theirselvesQ_t is very small compare to the actual volume of cutting ($Q_c^{'}$).). For one complete interval between tracking teeth the space available of working chain with W width is

$$Q_a = WSh_t \quad (11)$$

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

$$Q_a \geq Q_c^{'} \quad (12)$$

i.e.

$$WSh_t \geq K_b WSd \frac{U}{u_t}\left[1 - \frac{R}{d}\sin\phi\left(1 + \cos\phi - \sin\phi\right)\right]$$

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

or, with a long bar and small nose radius,

$$\frac{h_t}{d} \geq K_b \frac{U}{u_t} \qquad (14)$$

ACCELERATION AND TRANSPORT OF CUTTINGS

The minimum power needed for acceleration of cuttings N_T is given by the rate of supply of kinetic energy:

$$N_T = \frac{\rho . Q . u^2}{2}, \qquad (15)$$

where ρ is in-place density of the soil, u is the absolute tool speed. and Q the volumetric production rate:

$$Q = U.W.d, \qquad (16)$$

Where U is traverse speed, W is width of working chain. When U/u_t is small, as is usually the case, absolute tool speed u ≈ tangential tool speed u_t. The corresponding force F_T is

$$F_T = \frac{\rho . Q . u_t}{2}, \qquad (17)$$

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 surfaceh_t = 65 mm. The machine can make a single-pass traverse of a3 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 Φ = 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

$$\frac{h_t}{d} \geq K_b \frac{U}{u_t}$$

$\frac{h_t}{d}$ = 65/1200 = 0,05417

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

$K_b \frac{U}{u_t}$ = 2,6.3/240 = 0,0325 (with u_t = 240 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.

CONCLUSIONS

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 design 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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