THEORETICAL JUSTIFICATION OF THE HARROW WITH THE ACTIVE TEETH

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ABSTRACT

The article presents theoretical studies of the harrow with active teeth. The kinematic scheme of a tooth harrow with a crank mechanism is presented. The impact process of one tooth on a soil lump and its destructive speed were studied. The parameters of the crank mechanism of the harrow are determined.

KEYWORDS: *Tooth Harrow, A Crank Mechanism, Soil Lump, The Rate Of Destruction.*

INTRODUCTION

Existing agricultural tillage machines have passive working bodies, the operation of which does not meet agrotechnical requirements. In this regard, the same operation is performed by several passes of the unit, for example, loosening, crushing and soil compaction. As a result, the soil is over compacted due to the impact of the tractor propellers. The running systems of tractors during the period of pre-sowing tillage and sowing cover with traces from 30 to 80% of the field surface. Some sections of the field are exposed to 3-9 times the impact of propellers **[1, 2]**.

MATERIALSANDMETHODS

A harrow with active teeth has been developed at the Karakalpak Institute of Agriculture and Agrotechnology **[3]**. This tooth harrow is designed for crushing soil clods after ploughing when preparing the field for sowing.

The working section consists of rows of teeth fixed to a common mesh frame. And the working section itself is connected to the harrow frame with the help of tensioned cylindrical springs from the front and rear sides of its frame (Fig. 1).

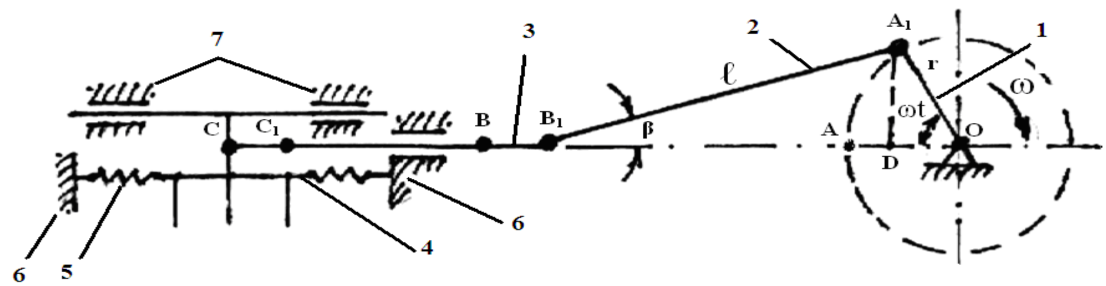

Fig. 1.Schematic diagram of a harrow with active teeth:

1 crank; 2-rod; 3-pusher of the working section; 4-working section with active teeth; 5-springs; 6 harrow frame; 7 guide bushings.

As a driver of the working section, a central crank mechanism is used. Let's explore the working process of the toothed harrow.

During the operation of the unit, the working section of the harrow makes a harmonious oscillatory movement with the help of a crank mechanism. In this case, each tooth of the harrow impulsively hits the soil clods.

Consider the impact process of one tooth on soil clods. The impact process is usually divided into two phases **[4]**: in the first phase, the relative velocity decreases, and in the second, it increases. The greatest force arises at the moment of completion of the first phase when the projections of the velocities of the colliding points on the normal to the surfaces at the point of impact are equal, and the deformation of the surfaces is the greatest. The maximum force is obtained from the expression.

$$\Delta T = A, \qquad (1)$$

where: ΔT is the kinetic energy expended in the first phase of impact;

A – the work of deformation of elastic links as the force increases from *0* to P_{max}.

We find the value of *ΔT* under this assumption, we consider that there are gaps in the hinges of the crank mechanism, and the pusher is rigidly connected to the working section. Therefore, the impact is experienced, first by the pusher with the working tooth, and then - after the gap is sampled - by the rest of the mechanism.

Let us determine *ΔT*of the crank mechanism with a pusher. A pusher with a working tooth at a speed υ hits a lump of soil with a mass of M (Fig. 2).

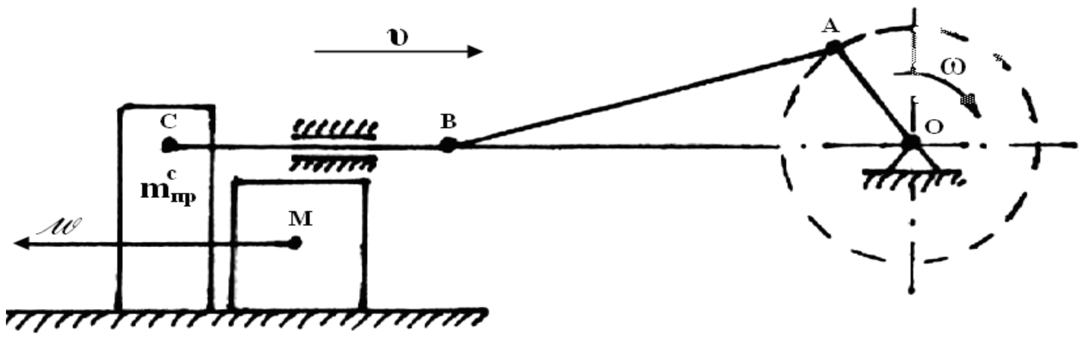

Fig. 2.Scheme for determining the kinetic energy ΔT of the mechanism

Denote by m^c_{np} bringing to point C the mass of the mechanism with a working tooth. We calculate this mass, as usual, from the condition of equality of its kinetic energy and the energy of the mechanism. The equation of motion of the mechanism under the action of the impact force P (neglecting the rest of the active forces) has the form

$$m^c_{np}W_c + \frac{1}{2}\upsilon_c^2\frac{dm^2_{np}}{dS_c} = P. \qquad (2)$$

The second term on the left side of the equation is discarded when determining the motion in the event of an impact. Then the impact force from the reduced mass of the mechanism with one working tooth will be

$$m^c_{np}\cdot W_c = P. \qquad (3)$$

The impact force of the total working section of the harrow will be

$$nm^c_{np}\cdot W_c = P.$$

where: *n* is the number of teeth of the working section.

We determine the kinetic energy expended in the first phase of the impact. At the end of the first phase of impact (*t* = *r*), the speed of the pusher with one working tooth:

$$\upsilon^1 = \upsilon - W_c\tau = \upsilon - \frac{P\tau}{m^c_{np}}. \qquad (4)$$

Mass velocity *M*at*t* = *τ*

$$\upsilon'' = \frac{P\tau}{M}. \qquad (5)$$

Equatingυ^1andυ^{11}, we find the magnitude of the shock impulse in the first phase of the impact

$$S_1 = P\tau = \upsilon\mu;$$

$$\frac{1}{\mu}=\frac{1}{M}+\frac{1}{m_{np}^{c}}. \quad (6)$$

Substituting the value of S_1 into formula (5), we obtain

$$\upsilon''=\upsilon'=\frac{\upsilon\mu}{M}=\upsilon\frac{m_{np}^{c}}{M+m_{np}^{c}}.$$

Consequently

$$\Delta T=\frac{1}{2}m_{np}^{c}\cdot\upsilon^{2}-\frac{1}{2}(m_{np}^{c}+M)\upsilon^{2}=\frac{1}{2}m_{np}^{c}\upsilon^{2}\frac{M}{M+m_{np}^{c}}. \quad (7)$$

Thus, the kinetic energy expended in the first phase of impact, which is equivalent to the work performed, depends on the reduced mass m_{np}^{c} mechanism with a working body and the mass of the soil lump M, as well as the speed υ of the working body.

Determine the destructive speed of impact. For the material (soil clod) to collapse, the impact must occur at a speed exceeding the limiting speed for elastic deformations, equal to the speed of propagation of vibrations in this material **[5]**.

The material is destroyed if the external forces applied to it exceed the internal cohesive forces of the particles of the material.

It is known that the breaking stress

$$\sigma_{разр}=\frac{Ea}{Д}, \quad (8)$$

where: E – the modulus of elasticity of the soil clod, Pa;

a – the value of elastic deformation, m, (Fig. 3), (the soil clod is conventionally taken in the form of a ball);

$Д$ – the diameter of the stressed part of the lump, to which vibrations propagate, m.

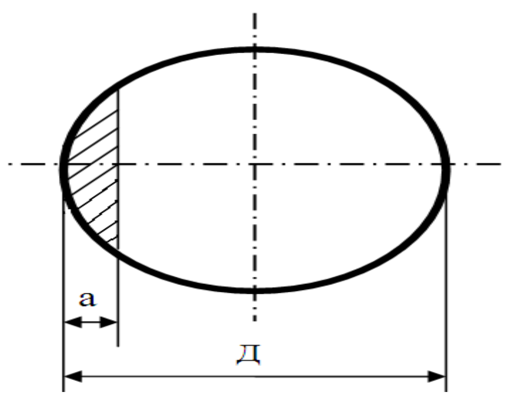

Fig.3. Scheme of elastic deformation of a soil clod.

The soil clod is taken as a brittle material, then the breaking stress will be greater than or equal to the tensile strength of the material

$$\sigma_{разр} \geq \sigma_{пр.пр.} \qquad (9)$$

The values of*a*and*Д*are found by the formulas:

$$a = v\Delta t \text{ and } Д = c\Delta t$$ **Error! Bookmark not defined.**

where: υ – impact speed; Δt – the impact time; c – e speed of vibration propagation.

The value of c is determined by the formula

$$c = \sqrt{\frac{E}{\rho}},$$

whereρ – the density of the soil clod, kg/m^3

Сопоставляя вышеприведенные формулы, находим разрушающую скорость удара.

$$v_{разр} = \sigma_{разр}\sqrt{\frac{E}{\rho}} / E \qquad (10)$$

Thus, for the material to fail, the impact must occur at a speed exceeding the speed υ for elastic deformations.

The working section of the toothed harrow makes oscillatory movements with the help of a crank mechanism. The main parameters and modes of operation include the length of the crank radius *r*, the ratio of the length of the crank radius to the length of the connecting rod - *r/ℓ*, the crank rotation frequency n and the speed of the destructive impact$\upsilon_{разр}$.

It has been established that in order to reduce the inertial and normal forces arising in the working section when it performs a harmonic oscillation, it is advisable to take the ratio of the length of the crank to the length of the connecting rod within*r/ℓ = 0,23 - 0,30*[6].

From design considerations, we will take the length of the crank radius *r* =40 mm. If the ratio*r/ℓ*we take within the specified limits, i.e. equal to 0.25, then the connecting rod length should be ℓ = 160 mm.

The crank rotation frequency n can be found from the relation

$$v_{разр} = \pi \cdot r \cdot n / 30 \qquad (11)$$

We determine the numerical values of $\upsilon_{разр}$and*n.*

To do this, we use the data of [7]:

$E = 1{,}9 \cdot 10^6$ Pa– lump elasticity modulus;

$\rho = 1050$ кг/м^3 – is the lump density.

According to equation (9), we have

$$\sigma_{разр} = \sigma_{пр.пр.} = 11 \cdot 10^4\, Pa.$$

Then

$$v_{разр} = \sigma_{разр}\sqrt{\frac{E}{\rho}} / E = \frac{11 \cdot 10^4 \sqrt{1{,}9 \cdot 10^6 / 1050}}{1{,}9 \cdot 10^6} = 2{,}4\, м/с.$$

Crankspeed

$$n = \frac{\upsilon_{разр} \cdot 30}{\pi \cdot r} = \frac{2{,}4 \cdot 30}{3{,}14 \cdot 0{,}04} = 576\, об/мин,$$

where:r = 0,04 m- previously accepted length of the crank.

CONCLUSION

Thus, for effective destruction of the soil clod, the destructive speed of the working section with teeth must be at least 2.4 m/s, and the crank rotation speed must be at least 576 rpm. In this case, the length of the crank should be equal to0.04 m, and if the ratio of the crank to the length of the connecting rod is 0.25, then the length of the connecting rod is0.16 m.

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