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Research Article

RESEARCHING THE ANGLE OSCILLATIONS FORMING THE SOFT LAYER ON THE FIELD SURFACE OF BREAKING LEVELLERS

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ABSTRACT

The article notes that a suspended planner has been developed, equipped with a device that creates a soft layer of soil on the surface of the field. The leveler is designed with a central section and a side section that are pivotally connected to each other. The side sections are transferred from the working position to the transport position and from the transport position to the working position with the help of hydraulic cylinders. All sections consist of front and rear transverse and longitudinal braces connecting them to each other. The front cross brushes of the sections are equipped with leveling working bodies, and the rear cross brushes are equipped with compacting working bodies. Devices are installed on the rear crossbars of the sections, creating a layer of loose soil on the field surface. They consist of two rows of transverse beams equipped with teeth and are pivotally attached to the rear braces of the sections. To ensure the same depth of processing of the tool, its angular vibrations in the longitudinal vertical plane were studied. The results obtained show that for given operating conditions, the processing depth of the device is uniform at the level of requirements based on the correct selection of the thickness of its pressure spring.

KEYWORDS

Loosen-leveller, the device forming the soft soil layer on field surface, teeth, tension spring, smooth running of the device on tillage depth, angular oscillations of device, resistance and bending coefficients of soil per each tooth of the device, bending coefficient of device tension spring, set operating conditions

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INTRODUCTION

Nowadays, in our country in preparation of lands for planting installations consisting of loosen-leveller and spike tooth is widely used [1]. In this case, loosen-levellers smoothen the field surface, compact and grind large lumps at the required level, and toothed harrows form a soft soil layer on the field surface to provide the keeping the soil moisture. However, the installations consisting of loosen-levelling and spike tooth harrows have low productivity due to that they are trailers, inconvenient to use, and do not meet the principles of minimal and energy-saving tillage. Based on the above, suspended loosen-levellers was developed at the Scientific Research Institute of Agricultural Mechanization (SRIAM). The developed installation is equipped with a device creating a soft soil layer on the field surface [2]. It consists of central and right and left side sections, side sections are hinged to central sections and are transferred from operating position to transport position and from transport position to operating position us in hydraulic cylinders.

Each section of the loosen-levellers consists of anterior and rear transverse beams and longitudinal beams connecting them to each other, anterior transverse beams are equipped with leveling operating elements (levelers) and rear transverse beams are equipped with sealing operating elements (compactors). The central section is additionally equipped with a hanging device.

The rear transverse beams of sections are fitted with devices forming a fine soil layer on the field surface. They consist of two rows of transverse beams equipped with teeth and columns, each of them is hinged to rear transverse beams of sections by means of two longitudinal pulls.

In an effort to adjust the depth of immersion of teeth in soil, the devices are equipped with tension springs functioning on expansion.

Figure 1 shows a structural diagram of the central section of the loosen-levellers developed.

This article presents the results of studies implemented to ensure a smooth running of loosen-levellers along with the processing depth.

Due to variation of physical and mechanical properties of soil, longitudinal R_x and vertical R_z reaction forces acting on teeth of the device by soil are constantly variating (Fig. 2). As a result, in addition to the forward motion the in longitudinal-vertical plane, device also has forced angular oscillations with respect to *O* point (hinge). It leads to varying in depth of immersion of teeth in soil, and as a result, tillage depth is not ensured smoothly.

MATERIALS AND RESEARCH METHODS

Amplitude of angular oscillations in its longitudinal-vertical plane should be as small as possible to ensure that soil at a flat depth by device teeth. To solve this problem, we construct the differential equation of angular oscillations of this device and let's solve it.

In effort to create a differential equation of angular oscillations of device, we accept the following constraints:

- Plowing unit moves in a straight line and at the same speed;
- Frictional forces on *O*-hinge connecting the device to its bracket are low and do not affect its oscillations;
- Linear and angular oscillations of loosen-leveler's

do not affect the oscillations of device around O-hinge;

- Equilibrium position of longitudinal traction of device is in horizontal position and its deviation from this position is at small angle.

Based on those accepted constraints and calculation scheme shown in Figure 2, the differential equation of angular oscillations of device with respect to point O will be as in the following [3]:

$$J\frac{d^2\alpha}{dt^2} = m_m g l_2 - R_z l_1 - R_x\left(l_5 + l_1\alpha\right) + n_n Q_n \frac{l_3 l_4}{\sqrt{l_3^2 + l_4^2}}, \quad (1)$$

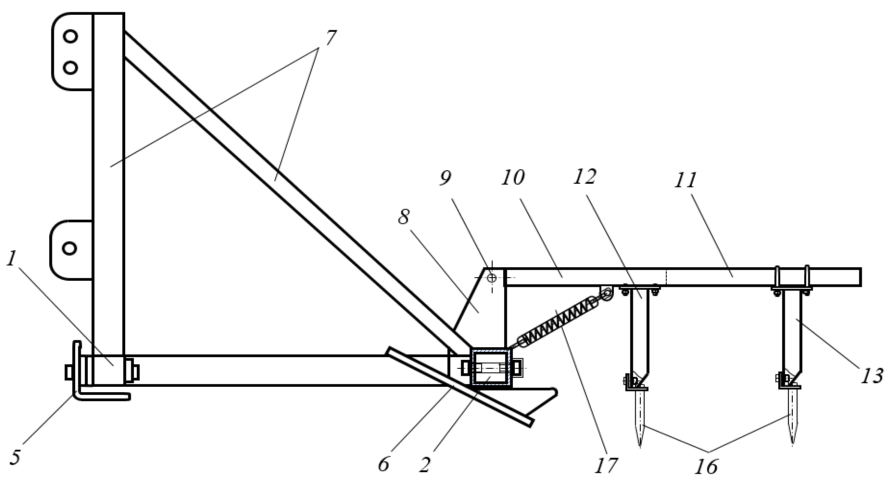
In this case

J – moment of device inertia with respect to point O, kgm²;

α – angle of deviation of longitudinal tension of device from the balance, rad;

t – time, s.

m_m – mass of device, kg;



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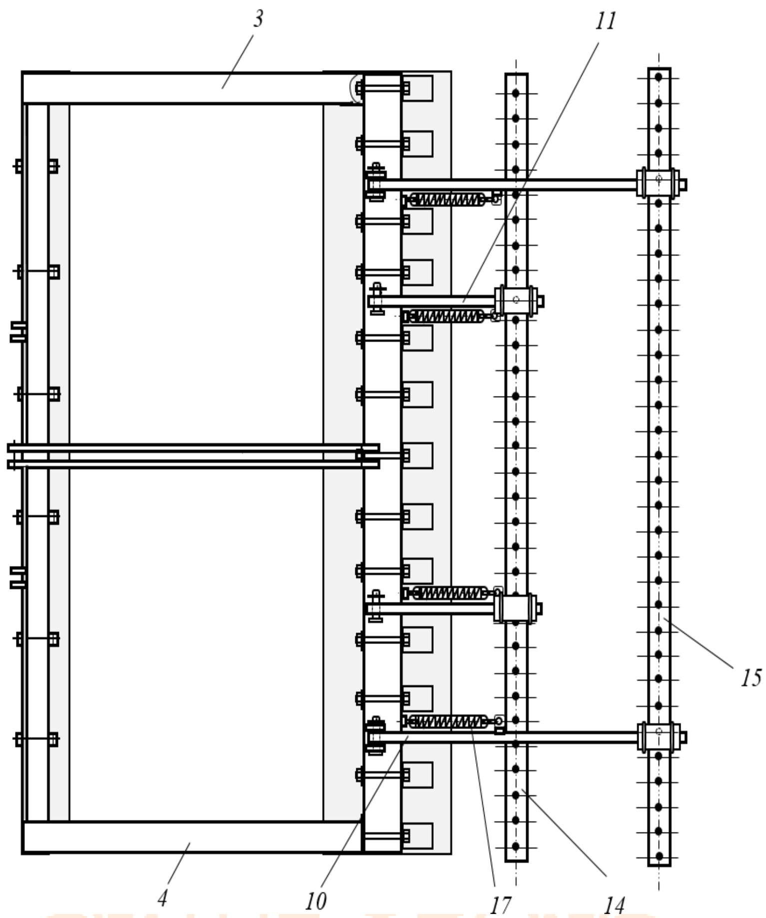

1, 2-transverse beams of central section loosen-leveler; 3, 4-longitudinal beams;
5-levellers; 6-compactors; 7-central section hanging device; 8-brackets; 9-fingers;
10, 11- longitudinal traction; 12, 13-columns; 14, 15 transverse beams; 16-teeth;
17-spring-loaded springs

Figure 1. Schematic diagram of the central section of loosen-leveler's equipped with installation forming a fine soil layer the on-field surface

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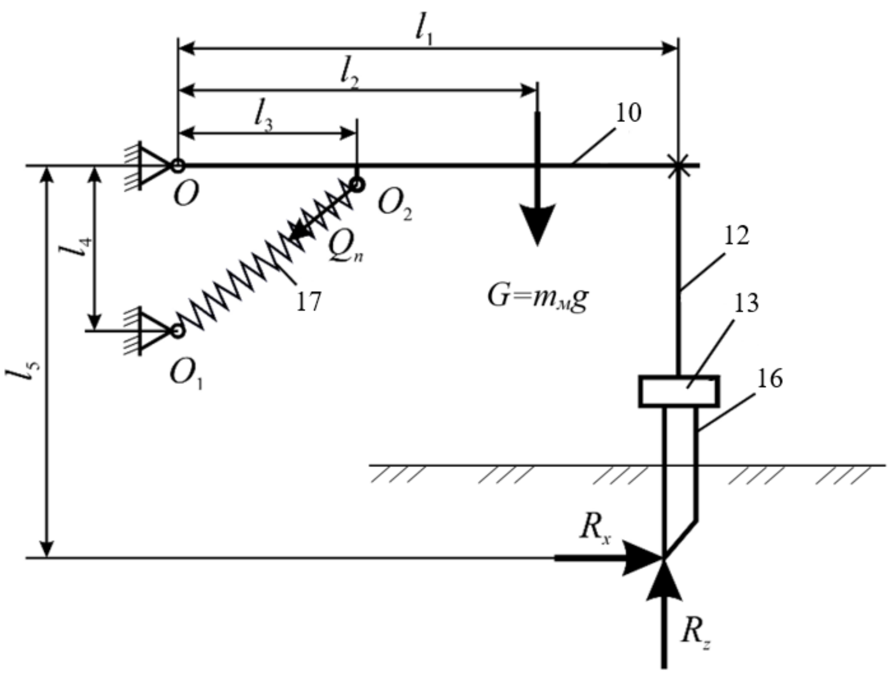

10-longitudinal traction; 12-pole; 13-transverse beam; 16-tooth; 17-spring

Figure 2. Forces influencing to the device in operation process

g – acceleration of free fall, m/s^2;

l_1 – length of longitudinal traction of device, m;

l_2 – longitudinal distance from the hinge to the point where the weight of the device is set, m;

l_3 – longitudinal distance between O and O_2 points, m;

l_4 – vertical distance between O and O_1 points, m;

l_5 – vertical distance from the tip of device's teeth to O point, m;

n_n – number of springs mounted on single device, pcs;

Q_n – spring tension force, N.

Considering that R_x and R_z reaction forces affecting on the device depend on amount and rate of soil deformation under the influence of its teeth, and it consists of set variable forces arising from variability of physical and mechanical properties of soil and formulating them through the physical and mechanical properties of soil and device parameters [4 -7], we will achieve such equation (1) as in the following.

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$$J\frac{d^2\alpha}{dt^2}+n_m b_m l_1^2\frac{d\alpha}{dt}+\left\{n_m c_m l_1^2+n_m P_m l_1+n_n\frac{c_n l_3^2 l_4}{\sqrt{l_3^2+l_4^2}}\right\}\alpha=\Delta R_z(t)l_1. \qquad (2)$$

in this case

n_m – number of teeth mounted on to device, pcs;

b_m – coefficient resistance of soil attempted per single tooth of device, N·s/(m· tooth);

c_m – resiliency coefficient of soil attempted per single tooth of device, N/(m· tooth);

P_m – resistance of device single tooth to gravitation, N;

c_n – resiliency coefficient of tension spring of device, N/m;

$\Delta R_z(t)$ – variable force affecting onto the device, N.

(2) in order to solve equation $\Delta R_z(t)$ let's consider as $\Delta R_z(t)$ the force will be varied according to the law of harmonics, which means

$$\Delta R_z(t)=n_m\sum_{n=1}^{n_i}\Delta R_z^n\cos n\omega t, \qquad (3)$$

In this case

ΔR_z^n – amplitude of related harmonics attempted to single tooth, N;

$n=1,2,\ldots,n_i$ – numbers of harmonics;

ω – $\Delta R_z(t)$ rotational frequency of force, s^{-1}.

(3) when formula is considered (2) the equation will be as in the following:

$$J\frac{d^2\alpha}{dt^2}+n_m b_m l_1^2\frac{d\alpha}{dt}+\left\{n_m c_m l_1^2+n_m P_m l_1+n_n\frac{c_n l_3^2 l_4}{\sqrt{l_3^2+l_4^2}}\right\}\alpha=$$

$$=n_m\left(\sum_{n=1}^{n_i}\Delta R_z^n\cos n\omega t\right)l_1. \qquad (4)$$

RESEARCH RESULTS AND ITS DISCUSSION

(4) equation variable $\Delta R_z(t)$, representing the forced angular oscillations under the influence of alternating forces, will be as in the following [3]:

$$\alpha(t)=\frac{n_m\left[\sum_{n=1}^{n_i}\Delta R_z^n\cos(n\omega t-\delta)\right]l_1}{J\sqrt{\left\{\frac{1}{J}\left[n_m\left(c_m l_1^2+P_m l_1\right)+n_n\frac{c_n l_3^2 l_4}{\sqrt{l_3^2+l_4^2}}\right]-(n\omega)^2\right\}^2+\left(\frac{n_m b_m l_1^2}{J}\right)^2(n\omega)^2}}, \quad (5)$$

In this case $\delta=arctg\dfrac{n_m b_m l_1^2(n\omega)}{n_m\left(c_m l_1^2+P_m l_1\right)+n_n\frac{c_n l_3^2 l_4}{\sqrt{l_3^2+l_4^2}}-J(n\omega)^2}$.

On the basis of (5) the maximum deviation angle from equilibrium position of longitudinal hand ladle will be as shown below.

$$\alpha_{\max}=\frac{n_m\left(\sum_{n=1}^{n_i}\Delta R_z^n\right)l_1}{J\sqrt{\left(\frac{1}{J}\left[n_m\left(c_m l_1^2+P_m l_1\right)+n_n\frac{c_n l_3^2 l_4}{\sqrt{l_3^2+l_4^2}}\right]-(n\omega)^2\right)^2+\left(\frac{n_m b_m l_1^2}{J}\right)^2(n\omega)^2}}. \quad (6)$$

By using this formula, let's determine the maximum deviation $\Delta h_{\max}$ of tillage depth of device from the set

$$\Delta h_{\max}=\pm l_1\sin\alpha_{\max}=$$

$$=\pm l_1\sin\left\{\frac{180}{\pi}\cdot\frac{n_m\left(\sum_{n=1}^{n_i}\Delta R_z^n\right)l_1}{J\sqrt{\left(\frac{1}{J}\left[n_m\left(c_m l_1^2+P_m l_1\right)+n_n\frac{c_n l_3^2 l_4}{\sqrt{l_3^2+l_4^2}}\right]-(n\omega)^2\right)^2+\left(\frac{n_m b_m l_1^2}{J}\right)^2(n\omega)^2}}\right\}. \quad (7)$$

From above from the analysis of this formula we can see that a plane of tillage (processing) depth depends on its parameters and dimensions (J , l_1, l_3 , l_4 , n_m , c_n), physical and mechanical properties of soil (c_m , b_m), forces affecting on it (ΔR_z^n , P_m).

In order to get flat soil tillage at the required level, the value of Δh should be less than ±1 cm [8, 9]. For provided operating condition, this is achieved at the account of that the resiliency of device tension spring is properly selected.

CONCLUSIONS

Results of theoretical studies show that for a set operating condition based on fact that the tillage depth of device of the loosen-leveler's forming a fine soil layer on field surface at the required level and smoothly running is achieved at the account of properly selecting the resiliency of tension spring.

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