Research Results on Vibration Movement in Longitudinal-Vertical Plane of the Device Leveler that Form Soft Layer on the Field Surface of Wide-Range Chisel-Cultivator

Abdusalim Tukhtakuziev, Bobir Bozorovych Rajabov
Scientific and Research Institute of Agricultural Mechanization (SRIAM)
abdusalim_1950@mail.ru, bobrajabov@gmail.com

Abstract: Developed comprehensive chisel-cultivator in effort to level the surface on the field and create a soft soil layer on it was specified in the article. The device is designed composing the levelers that consists of soil pushing plates and roller-crushers. Levelers are connected through hinges to transverse and longitudinal brushes of central and side sections of chisel-cultivator by means of parallelogram mechanisms, and roller-crushers by means of pulling devices. In order to ensure smooth leveling of field surface, the vibrating movement of device leveler in the longitudinal-vertical plane was researched. In this case, differential equation of forced vibrations of leveler was formulated and solved using the theory of vibrations and the basic laws of higher mathematics. According to obtained results, leveling of the field surface at required level by device leveler is achieved due to the correct selection of its mass and deviation angle of longitudinal pulling devices of the parallelogram mechanisms from horizon. In the work process, if it is ensured that longitudinal pulling devices of the parallelogram mechanisms occupy horizontal position or close to it, amplitude of vertical vibrations of leveler will have a minimum value and there will be achieved qualitative leveling of the field surface.

Keywords: comprehensive chisel-cultivator, a device that levels the field surface and forms fine soil layer, leveler, soil pusher plate, rolling device, parallelogram mechanism, traction, vertical forced vibrations of leveler, soil stiffness and resistance coefficients, mass of leveler, longitudinal pulls of parallelogram mechanisms, the angle of deviation of longitudinal pulls to the horizon during the work process.

Introduction

It is known that currently tractors such as "Magnum 8940", MX-255, T 7060, ARION-630S, AXION-850 are widely used in the main and pre-sowing cultivation activities on land areas of our Republic. In effort to using them, comprehensively a chisel-cultivator was developed at Scientific-Research Institute of Agricultural Mechanization [1,2]. It consists of central as well as right and left side sections (parts); the side sections are connected with central section through longitudinal hooks and are transferred from operating position to transport position and from the transport position to operating position by means of hydraulic cylinders. Developed comprehensive chisel-cultivator is equipped only with softening device and arrow-shaped claws, and therefore, in process of work, it only softens the land soil. Additionally harrowing and grinding operations are carried out to level the field surface and create soft soil layer on it. It leads to excessive soil compaction, increased labor and other expenditures, including fuel consumption.
Based on above, we have developed comprehensive chisel-cultivator device that levels the field surface and forms a soft soil layer on it (Fig. 1). It consists of levelers and plate rolling devices made in the form of earth-moving plates. The levelers are mounted in the center of arrow-shaped claws, and plane rolling devices are mounted one on each section of chisel-cultivator. Levelers are parallelogram mechanisms, and rolling devices are hinged to the longitudinal and rear transverse brushes of the chisel-cultivator sections by means of pulling devices [3].

In the work process, mitigating device and arrow-shaped claws of chisel-cultivator mitigate the soil to the specified depth, levelers flatten (smooth) out the unevenness formed after them, plate rolling device requires soil level and forms a soft soil layer on its surface that ensures moisture retention and qualitative sowing of seeds.

The results of studies on smooth running of the device leveler developed for a comprehensive chisel-cultivator in the longitudinal-vertical plane are specified in this article.

**Scientific Research methods.** In the article, basic laws and rules of the vibration theory were applied, and theoretical research activities were implemented in effort to ensure smooth movement of the device leveler designed for a comprehensive chisel-cultivator in the longitudinal-vertical plane.

Gravity force on the leveler in the longitudinal plane

\[ G_m = m_m g \]

(here \( m_m \) – levelers mass, kg; \( g \) – acceleration of free fall, m/s²), longitudinal \( R_X \) and vertical \( R_Z \) reaction of soil as well as traction force \( P \) put by the longitudinal pulling devices will affect (Figure 2).

Due to variability of physical-mechanical properties of soil (moisture, density, hardness and others) \( R_X \) and \( R_Z \) forces affecting onto the leveler will vary always.

As a result, in work process, the leveler, in addition to forward movement with chisel-cultivator in longitudinal-vertical plane, also makes forced vibrating movement in vertical direction. It leads to decreasing the smoothness degree of field surface. Based on this, let’s study forced vertical vibrations of the leveler in longitudinal flatness and consider the conditions for their amplitude to have minimum value. In effort to perform it, let’s construct and solve the differential equation of vibrations of leveler vertically, that is, along its \( Z \) axis (Fig. 2). In this case, let’s presume that forward movement of unit is constant and let’s consider that friction forces in parallelogram mechanism hinges the leveler are small and do not affect its vertical vibrations.

**Research results and their discussions.** In accordance with the accepted constraints and scheme shown in Fig. 2.
differential equation of forced vertical vibrations of the leveler will have following form [4-7].

\[ m_m \frac{d^2 Z}{dt^2} = m_m g - R_z - P \sin \varepsilon, \]  \hspace{1cm} (1)

either when it is considered as \( P = \frac{R_x}{\cos \varepsilon} \)

\[ m_m \frac{d^2 Z}{dt^2} = m_m g - R_z - R_x \tan \varepsilon, \]  \hspace{1cm} (2)

here \( \varepsilon \) – deviation angle of pulling devices of the parallelogram relative to horizon, \(^{\circ}\); \( t \) – time, s.

Let’s formulate \( R_Z \) and \( R_X \) forces as shown in the below [4,5]

\[ R_Z = R_\delta + R_m + R_{Zt} \]  \hspace{1cm} (3)

\[ R_X = R_X^\dot{} + R_{Xt}, \]  \hspace{1cm} (4)

бунда \( R_\delta, R_m \) – those forces depending on quantity and velocity of the soil deformations by lines accordingly, that mean the elastic and resistance forces of soil, N; \( R_X^\dot{} \) – \( R_X \) average value of force, N; \( R_{Zt}, R_{Xt} - R_Z \) and \( R_X \) variable consistants of forces, N.

When we consider (3) and (4) formulas the formula (2) will be as in the following:

\[ m_m \frac{d^2 Z}{dt^2} = m_m g - \left( R_\delta + R_m + R_{Zt} \right) - \left( R_X^\dot{} + R_{Xt} \right) \tan \varepsilon. \]  \hspace{1cm} (5)

In the event if the leveler is in the static equilibrium

\[ R_\delta = \Delta_{cm} S_m C_m; \]  \hspace{1cm} (6),

\[ R_m = 0; \]  \hspace{1cm} (7),

\[ R_{Zt} = 0; \]  \hspace{1cm} (8),

\[ R_{Xt} = 0; \]  \hspace{1cm} (9)

here \( \Delta_{cm} \) – submersion depth of the soil pushing plates in static equilibrium state of the leveler, m; \( S_m \) – surface of supporting leveler, m\(^2\); \( C_m \) – coefficient of compaction of soil per unit area of the leveler support surface, N/m\(^3\).

When the leveler being at equilibrium status falls down to \( Z \) distance

\[ R_\delta = \left( \Delta_{cm} + Z \right) S_m C_m; \]  \hspace{1cm} (10),

\[ R_m = \dot{Z} S_m b_m; \]  \hspace{1cm} (11),

\[ R_{Zt} = -\Delta R_Z \left( t \right); \]  \hspace{1cm} (12), \( R_{Xt} = -\Delta R_X \left( t \right). \]  \hspace{1cm} (13).
in this case \( b_m \) – coefficient of the soil resistance per unit area of leveler support surface, N·s/m².

Let’s put the above values of \( R_\phi, R_m, R_{Zt} \) and \( R_{Xt} \) into equation (5), thus we will have the following

\[
m_m \frac{d^2 Z}{dt^2} = m_m g - \left[ (\Delta c_m + Z) C_m + \dot{Z} b_m \right] S_m +
+ \Delta R_Z(t) - \left( R_{Xt} - \Delta R_X(t) \right) t g \varepsilon.
\]

(14)

When the leveler is in the equilibrium position

\[
m_m g - \Delta c_m S_m C_m - R_{Xt} t g \varepsilon = 0.
\]

(15)

Considering this (14) equation will be as in the following:

\[
m_m \frac{d^2 Z}{dt^2} = - \left[ Z C_m + \dot{Z} b_m \right] S_m + \Delta R_X(t) t g \varepsilon + \Delta R_Z(t).
\]

(16)

Let’s formulate it as below:

\[
m_m \frac{d^2 Z}{dt^2} + S_m \dot{Z} b_m + S_m C_m Z = \Delta R_X(t) t g \varepsilon + \Delta R_Z(t).
\]

(17)

In effort to solve this equation, let’s consider that variable forces on its right side vary according to the harmonic law, i.e.

\[
\Delta R_X(t) t g \varepsilon + \Delta R_Z(t) = \sum_{n=1}^{n} \left( \Delta R_X^n t g \varepsilon + \Delta R_Z^n \right) \cos n \omega t.
\]

(18)

In this case \( \Delta R_X^n, \Delta R_Z^n \) – variable appropriately \( \Delta R_X(t) \) and \( \Delta R_Z(t) \) amplitude of forces harmonicas, N; \( n = 1, 2, \ldots, n_i \) – figure of harmonicas; \( \omega \) – rotational amplitude of variable forces, s⁻¹; \( t \) – time, s.

Taking (18) into account, equation (17) will be as in the following:

\[
m_m \frac{d^2 Z}{dt^2} + S_m \dot{Z} b_m + S_m C_m Z = \sum_{n=1}^{n} \left( \Delta R_X^n t g \varepsilon + \Delta R_Z^n \right) \cos n \omega t.
\]

(19)

By dividing \( m_m \) both sides of this equation, we will get the following formula

\[
\frac{d^2 Z}{dt^2} + \frac{S_m \dot{Z} b_m}{m_m} + \frac{1}{m_m} S_m C_m Z = \frac{1}{m_m} \sum_{n=1}^{n} \left( \Delta R_X^n t g \varepsilon + \Delta R_Z^n \right) \cos n \omega t.
\]

(20)

Solution of this equation representing the forced vertical vibrations of leveler and its amplitude will be as in the following [8-10]:

Copyright (c) 2022 Author(s). This is an open-access article distributed under the terms of Creative Commons Attribution License (CC BY). To view a copy of this license, visit https://creativecommons.org/licenses/by/4.0/
$Z(t) = \frac{1}{m} \sum_{n=1}^{n} \frac{\left( \Delta R_X^n t g \varepsilon + \Delta R_Z^n \right) \cos(n\omega t - \delta_n)}{\sqrt{\left[ \frac{S_m C_m}{m_m} - (n\omega)^2 \right]^2 + \left( \frac{S_m b_m}{m_m} \right)^2 (n\omega)^2}}$; \hspace{1cm} (21)

$A_m = \frac{1}{m} \sum_{n=1}^{n} \frac{\left( \Delta R_X^n t g \varepsilon + \Delta R_Z^n \right)}{\sqrt{\left[ \frac{S_m C_m}{m_m} - (n\omega)^2 \right]^2 + \left( \frac{S_m b_m}{m_m} \right)^2 (n\omega)^2}}, \hspace{1cm} (22)$

Here $\delta_n = \frac{S_m b_m (n\omega)}{S_m C_m - m_m (n\omega)^2}$.

It is self-evident that amplitude of vertical vibrations of leveling should have minimum value to ensure quality leveling of the field surface. Analysis of formulas (21) and (22) shows that this is mainly achieved due to the correct selection of its mass and deviation angle from the horizon of the parallelogram mechanism's longitudinal pulls. It should be noted that if the longitudinal traction of parallelogram mechanism is ensured to be horizontal or close to it during operation, the amplitude of vertical vibrations of the leveler will have a minimum value, and as result, quality leveling of the field surface will be ensured.

**Conclusion.** Required levelling of the field surface by leveler, which creates a soft soil layer on the surface of field developed for comprehensive chisel-cultivator, is mainly ensured by its mass and correct selection of installation angle of the parallelogram mechanism's longitudinal pullers relative to horizon. If parallelogram mechanism operates horizontally or close to horizontal position during the operation, the amplitude of vertical vibrations of leveler will have minimum value, and as result, quality leveling of field surface will be ensured.

**List of used literatures**


5. Tukhtakuziev A., Mansurov M., Karimova D. Scientific and technical principles of ensuring the stability of operating depth of the soil tillage machines with operating elements movably attached to framework - Tashkent, 2019. – p.84


