The study of the stability of the movement of the frontal working bodies of the combined aggregate for sowing seeds of re-crops, depending on the depth of tillage

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Abstract. This article theoretically investigates the stability of the movement of frontal working bodies for strip tillage of an energy-saving combined aggregate for sowing seeds of re-crops, depending on the depth of tillage. At the same time, a differential equation was compiled that describes the change in the working depth of tillage by the frontal working bodies of the aggregate. Based on the equation, the dependences of the change in the amplitude of the depth of tillage by the section of the working bodies of the combined aggregate and the stiffness of the pressure spring were studied.

1 Introduction

Long-term scientific studies of resource-saving tillage technologies show that the development of resource-saving combined aggregates that perform several processes at once, combining tillage and sowing of re-crops seeds, is a relevant task.

In addition, high-quality preparation of grain fields freed from winter crops and the development of a combined aggregate for sowing seeds of re-crops in accordance with agrotechnical requirements based on the agronomic background of the cultivated field are important.

The variability of the physical and mechanical properties of the soil and, consequently, the forces acting on the working bodies of the aggregate, lead to a change in their immersion depth and an uneven depth of tillage, which in turn adversely affects the required sowing quality and seed germination.
Based on the foregoing, we study the uniformity of the movement of the frontal working bodies of the combined aggregate for sowing seeds of re crops \(^{14-16}\), depending on the depth of tillage.

We accept the following restrictions:
- the aggregate moves at a constant speed;
- friction forces in the hinges of the parallelogram mechanism are very small and do not affect the movement of the working bodies in the longitudinal-vertical plane;
- linear and angular vibrations of the cultivator frame do not affect the working depth of the device;
- the support wheel of the aggregate is constantly pressed to the ground;
- sections of the parallelogram mechanism working bodies work in a horizontal position in the equilibrium position, and their deviation from this position is a small angle.

### 2 Methods

\[
m\ddot{Z} = mg + \sum R_\theta + Q_a - N_z
\]

\[
N_z = N_\theta + N_m
\]
In this Δсм – deformation of the soil under the action of the support wheel, in the position of the working bodies in a state of static equilibrium m; Ст – coefficient of soil stiffness per unit width of the rigidity of the support wheel Н/м²; Вт – support wheel hub width, m.

Δсм in expression (3) can be determined by the following expression [5],

\[ \Delta_{сm} = \frac{mg + Q_n + \sum R_z}{q_0 B_m D_m} \]

N_0 = \Delta_{сm} \cdot C_m B_m

N_c = \text{[constant value]}

Q_n = Q_c

Δсm = \Delta_{сm} + Z \cdot C_m B_m
In this – soil resistance coefficient per unit width of the support wheel N/m$^2$; Сп – spring rate, Н/м.

According to (2)–(5) and (7)–(9), equation (1), representing the change in the tilling depth of the working bodies under the action of the forces Rx and Rz, takes the following form:

$m\ddot{z} = mg + Q - ZC - \sum_{n=1}^{\infty} \Delta R^* - \sum_{n=0}^{\infty} n\Delta R^*_n \cos n\omega t$

We accept that the forces $\sum RZ$ acting on the working bodies change according to the harmonic law, i.e.

$\Delta RZ_n(t) = Z_n \sin n\omega t$

In this $RZ_n(t)$ – average value of power, Н; $\Delta RZ_n(t)$ – amplitude of variable force components, Н; $n=1, 2, \ldots, n_1$ – harmonic number; $n_1$ – number of the last recorded harmonic; $\omega$ – rotation frequency of power change, $s^{-1}$.

We substitute expression (11) into expression (10) and obtain

$m\ddot{z} = mg + Q - ZC - \sum_{n=1}^{\infty} \Delta R^* - \sum_{n=0}^{\infty} n\Delta R^*_n \cos n\omega t$

When the working bodies are in a state of static equilibrium.

$\sum RZ = 0$

$m\ddot{z} = mg + Q - ZC - \sum_{n=1}^{\infty} \Delta R^*_n \cos n\omega t$

Taking this expression into account, we write equation (12) in the following form

$m\ddot{z} = mg + Q - ZC - \sum_{n=1}^{\infty} \Delta R^*_n \cos n\omega t$

Or

$m\ddot{z} = mg + Q - ZC - \sum_{n=1}^{\infty} \Delta R^*_n \cos n\omega t$

It can be seen from the expression (15) that the immersion of the support wheel into the soil and, consequently, the change in the working bodies tilling depth are represented by an inhomogeneous secondary differential equation.
3 Results and discussion

The solutions of the equation (15) that determine the change in the tilling depth of the working bodies and the maximum amplitude of these changes are as follows

\[
Z(t) = \sum_{m}^{n} \frac{\Delta R_n^m (n \omega \delta - \delta_n)}{\sqrt{\left[\left(\frac{C_m B_m + C_n}{m}\right) - (n \omega \delta)^2\right] + \left(\frac{b_m B_m}{m}\right)^2 (n \omega \delta)^2}}
\]

\[
A = \frac{\Delta R_z^n}{\sqrt{\left[\left(\frac{C_m B_m + C_n}{m}\right) - (n \omega \delta)^2\right] + \left(\frac{b_m B_m}{m}\right)^2 (n \omega \delta)^2}}
\]

\[
\tan \delta_n = \frac{b_m B_m (n \omega \delta)}{(C_m B_m + C_n) - m(n \omega \delta)}
\]

\[
A \leq \Delta h
\]

\[
\sum_{m}^{n} \frac{\Delta R_n^m}{\sqrt{\left[\left(\frac{C_m B_m + C_n}{m}\right) - (n \omega \delta)^2\right] + \left(\frac{b_m B_m}{m}\right)^2 (n \omega \delta)^2}} \leq \Delta h
\]

\[
C_m = 1.7 \cdot 10^3 \text{ H/m}^2; B_m = 0.1 \text{ m}; b_m = 51.2 \cdot 10^{-3} \text{ c/m}^2; \Delta R_n^m = 300 \text{ H}; m = 70 \text{ kg}; n = 1; \omega = 2 \text{ c/s}; \phi_n = 10°; \mu = 0.3
\]
Fig. 2. Graph of the change in the amplitude of the change in the till depth of the working bodies depending on the spring rate $C_n$.

4 Conclusion

As a result of the above theoretical studies, the amplitude of the change in the working depth of the aggregate working bodies is taken equal to $\Delta h = 1$ cm.

It is graphically established that the spring stiffness of the parallelogram mechanism must be at least 82.7 N/cm.

It is determined that the compression force of the spring section of the aggregate, applied to the parallelogram mechanism, must be respectively not less than 334.5 N.

References


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