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Abstract. This article provides an important study of the vertical forces acting on the tractor unit. At the same time, it is shown that the undercarriage of a stationary tractor perceives the operating weight of the tractor itself, mounted agricultural machines and fertilizers. Thus, with a steady motion of the tractor unit, the values of the loads on the front and rear wheels change due to the resistance forces of the working tools and the rolling resistance force. And it is also shown that the rolling resistance force reduces the vertical loads on the steering wheel and the drive wheels are loaded by the same amount due to the redistribution of loads along the axles.

1. Introduction

The transport strategy of the Republic of Uzbekistan determines that the general goal of the functioning and development of tractor construction and the development of the automotive complex is to ensure economic growth, improve the quality of life and other vital national interests [1, 2, 3, 4]. At the same time, the territory of the Republic of Uzbekistan is divided into sub-zones with different crop rotations and cultivation technologies, climatic and soil conditions, annual volumes and terms of work that determine the structure and composition of machine and tractor parks. The development of agricultural production is unthinkable without a consistent and systematic technical re-equipment on the basis of exploited and new technology, the introduction of advanced technology, and further equipping farming and farms with machinery.

On the basis of the Strategic Actions for the further development of the Republic of Uzbekistan, the improvement of tract construction attaches great importance to making agricultural production a highly efficient and highly productive industry, significantly increasing the reliability of providing the country with agricultural products, and improving its quality.

The solution of the set tasks is possible on the basis of a further increase in the efficiency of the complex of machines used in cotton growing and, in particular, an increase in labor productivity of the quality of inter-row cotton processing. An increase in labor productivity in the international processing of cotton can be achieved by increasing the width of the capture, complex processing in one pass several operations or by increasing the working speed of the tractor unit [5, 6]. Many authors note [7, 8, 9, 10] that, first of all, one should think about the fact that agricultural processes can be carried out at higher speeds than now and it is important to maintain it during inter-row cultivation of crops. Based on this,

one of the topical issues is the study of such an important operational indicator as the study of vertical forces acting on a tractor unit.
In this regard, the article presents the results obtained by the method of economics and statistics, while it is shown that the technical and economic method is applicable for complex and expensive systems of units and assemblies that do not directly affect the safety of the biogas complex.

2. Method

Exploring the tractor unit E.F.Dvortsov during inter-row cultivation of cotton indicates [11] that the actual movement of the mounted unit is not rectilinear, but consists of segments of transition curves and straight sections. With the given data, the amplitude of the deviation of the trajectory during inter-row cultivation from the imaginary line of the rear direction varies within 5 - 20 cm with a period of 10 - 40 m.
M.L.Gusyatsky in his research as early as the second half of the last century determines the tractive power of a tractor from the distribution of the vertical load on its wheels [8].
The trajectory of the tractor when performing a particular agricultural operation can be described by a differential equation. When the differential equations match, many assumptions have to be made due to the complexity of the processes that take place during the movement of tractor units. The required trajectory, which is limited by agrotechnical requirements, mainly depends on the stability of the straight-line movement and controllability of the tractor unit.
In practice, as experiments carried out in the Syrdarya region of the Republic of Uzbekistan have shown, the maximum moisture content at which a satisfactory quality of soil cultivation in the aisles is possible is 16 ... 18%, and the specific shear resistance of gray soils is 0.107 ... 0.02 kg / cm^2, which corresponds to the minimum value.

3. Results and Discussion

Considering the above, as a rule, the undercarriage of a stationary tractor perceives the operating weight of the tractor itself, mounted agricultural machines and fertilizers. With a steady motion of the tractor unit, the values of the loads on the front and rear wheels change due to the resistance forces of the working tools and the rolling resistance force.

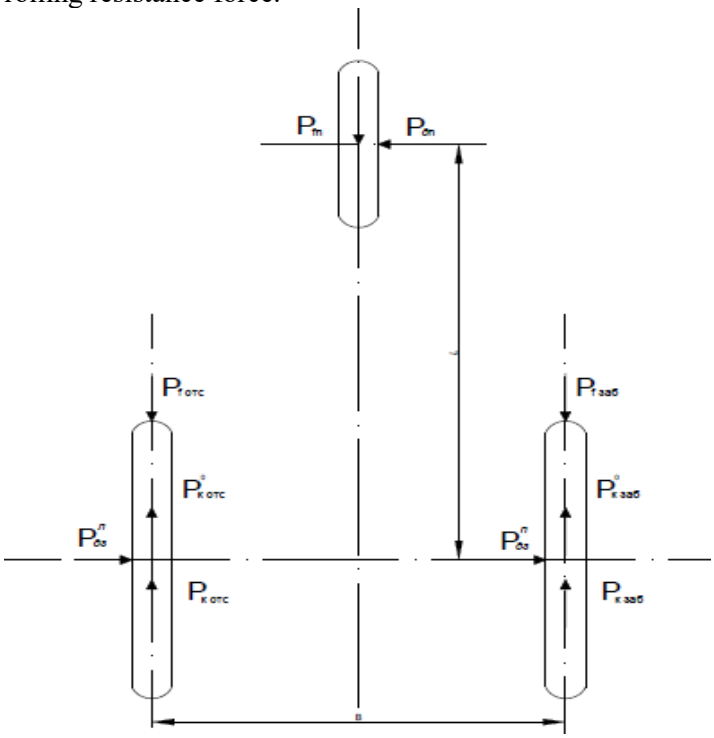

Figure 1. Diagram of the forces acting on the tractor unit when it deviates from the straight-line trajectory

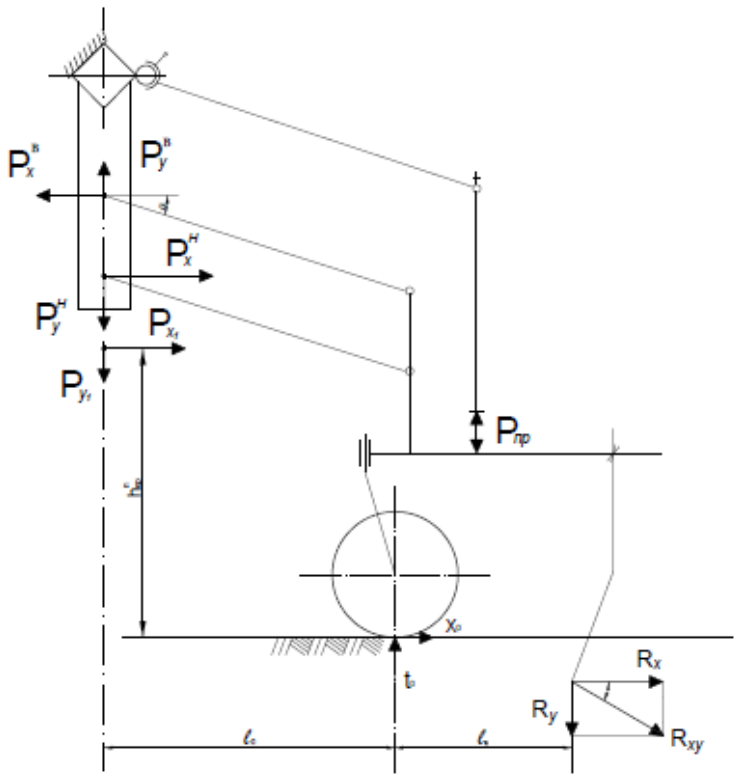

Figure 2. Diagram of the forces acting on the cultivator section

Consider the action of external forces and moments on the tractor unit at steady state motion.
The redistribution of the mass of the tractor unit characterizes the change in the magnitude of the loads. The wheels on the axle. The magnitude of the loads on the idler wheel is determined by drawing up the equation of moments relative to the point $O_К$ (Figures 1 and 2).

$$Z_н Z_к + P'_x h' + P''_x h'' - P_y \cdot l_1 - G_{a2} \cdot a_{a2} + M_R + M_{ск} \quad (1)$$

Replacing:

$$M_R = Z_н \cdot f_н \cdot K_н; M_{ск} = Z_к \cdot f_к \cdot Ч_к;\ Z_н + Z_к = G_u \quad (2)$$

We get:

$$Z_н = \frac{G_u(a_u - f_к K_к) - P'_x h' - P''_x h'' + P_y \cdot l_1}{Z + f_н \cdot K_н - f_к \cdot K_к}$$

In inter-row cultivation of cotton, the steering wheel moves on a relatively dense soil than the drive wheels, therefore their rolling resistance coefficients are different.
To determine the loads on the drive wheels, we will compose the projections of all acting forces on the vertical plane.

$$Z_к + Z_н - P'_z - G_u = 0 \quad (3)$$

Substituting the value $Z_н$ we get:

$$Z_к = \frac{G_u(Z - a_u - f_н K_к) + P'_x h' + P''_x h'' + P'_z(Z - l_1) + P''_z Z}{Z + f_н \cdot K_н - f_к \cdot K_к} \quad (4)$$

Equations (2) and (4) consist of two parts:
The former characterize the statistical load on the front and rear axles.

$$Z_{Ncm} = \frac{1}{Z} G_u \cdot a_u;$$

$$Z_{KNcm} = \frac{1}{Z} G_u \cdot (Z - a_u) \tag{5}$$

and the rest characterize the actual values of the redistribution of the loads of the tractor unit when it moves with a hook load.

$$\Delta Z_{\text{н}} = \frac{G_u \cdot a_u (f_{\text{н}} \cdot K_{\text{к}} - f_{\text{к}} \cdot K_{\text{к}} + f_{\text{к}} \cdot K_{\text{к}} Z) - (\text{P}'_{\text{x}} h' + \text{P}''_{\text{x}} h'' - \text{P}_{\text{y}} \cdot l_1) Z}{Z(Z + f_{\text{н}} K_{\text{к}} - f_{\text{к}} K_{\text{к}})}$$

$$\Delta Z_{\text{к}} = \frac{G_u \cdot Z^2 + 2G_u \cdot (Z - a_u) Z + G_u (Z - a_u)(f_{\text{н}} \cdot K_{\text{к}} - f_{\text{к}} \cdot K_{\text{к}})}{Z + f_{\text{н}} K_{\text{к}} - f_{\text{к}} K_{\text{к}})} \quad -$$

$$- \frac{G_u \cdot Z(a_u - f_{\text{н}} \cdot K_{\text{к}})[\text{P}'_{\text{x}} h' + \text{P}''_{\text{x}} h'' + \text{P}'_{Z}(Z + l_1) + \text{P}''_{Z} Z] \cdot Z}{Z + f_{\text{н}} K_{\text{к}} - f_{\text{к}} K_{\text{к}}} \tag{6}$$

As can be seen from dependencies (6), the vertical loads on the supports are not constant, but depend on the speed and load mode of the tractor unit, on the position of the center of gravity coordinate and the attachment point of the agricultural equipment, on the physical and mechanical properties and soil moisture. From equation (6) it can be seen that the unloading of the guide wheel occurs due to a change in the horizontal components of the resistance forces of the working tools and the resistance to wheel rolling, and the additional load on it arises only from the vertical component of the resistance force of the working tools and its point of application relative to the longitudinal axis of the tractor. An increase in the resistance forces of the working implements of the unit contributes to the additional loading of the leading ones, which in turn increases the traction properties of the tractor. Unloading the guide wheel $Z_{\text{н}}$ to a certain limit may not disturb the stability of the straight-line movement and the controllability of the tractor unit. Therefore, there is a minimum allowable load for each process. The criterion for setting the minimum load is the coefficient of lateral adhesion of the steering wheel to the soil, dynamic longitudinal stability and traction-coupling properties of the tractor. The minimum load on the idler wheel Z_{nmin} determines the optimal mass on it, and this will allow additional load on the drive wheels, if possible. This is especially important for tractors of cotton modification, where the size of the code part is limited by agrotechnical requirements and it is impossible to ensure traction-coupling properties by increasing the tire.

We determine the vertical loads acting on the tractor unit in the transport position of the working tools.

The chassis absorbs the weight of the tractor and agricultural machine; in motion, the loads are redistributed along the guide and driving wheels.

Consider the sum of the moments of all forces acting on the tractor relative to the point $O_{\text{к}}$ (Figure 1), we get:

$$Z_{\text{н}} \cdot Z - G_u \cdot a_u + \text{M}_R - \text{M}_{\text{ск}} = 0$$

$$Z_{\text{н}} = \frac{G_u \cdot a_u - \text{M}_R - \text{M}_{\text{ск}}}{Z}$$

$$Z_{\text{к}} = \frac{G_u (Z - a_u - f_{\text{к}} \cdot K_{\text{к}})}{Z + f_{\text{н}} \cdot K_{\text{н}} - f_{\text{к}} \cdot K_{\text{к}}} \tag{7}$$

Let's compose the equation of moments with respect to the points $O_{\text{н}}$ and define $Z_{\text{к}}$

$$Z_{\text{К}} = \frac{G_u(Z - a_u - f_{\text{К}} \cdot K_{\text{К}})}{Z + f_{\text{Н}} \cdot K_{\text{Н}} - f_{\text{К}} \cdot K_{\text{К}}} \quad (8)$$

From equations (7), (8) it can be seen that the rolling resistance force reduces the vertical loads on the steering wheel and the drive wheels are loaded by the same amount due to the redistribution of loads along the axes. In such cases, the most significant feature of the operation of agricultural tractor units is the random nature of external influences, which determines its output indicators.

4. Conclusions

The main task of the theory of complex systems should be considered the development of methods that, on the basis of their functioning, allow obtaining the characteristics of individual elements and analyzing the interaction between these elements and the external environment, determining the characteristics of the system as a whole. At the same time, with a steady motion of the tractor unit, the values of the loads on the front and rear wheels change due to the resistance forces of the working tools and the rolling resistance force. In addition, an analysis of the characteristics of external influences of such reactions to the operation of machine-tractor units shows that when solving many problems it is necessary to take into account external factors that determine the main laws of various processes. The process of work of cotton-growing tractors with aggregates can be represented in the form of a set of states - vectors of output quantities: agrotechnical, technological, kinematic, energy-power, and etc.

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