THEORETICAL STUDY OF THE MOTOBLOCK STABILIZING ON A SLOPE WORKS

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Abstract: *One of the most acute problems in the effective use of small-sized agricultural machinery, in particular, motor blocks, is the stabilization of their rectilinear motion on the slopes work. The purpose of this study is to increase the stabilizing moment of the motor block, by theoretically justifying its movement across the slope with a stabilizing device. The research uses modeling methods, theoretical mechanics and higher mathematics. As a result of the theoretical study, the conditions for the balance of the running wheels of the aggregate in the structure of the motor block and the agricultural implement when moving along the slope surface, as well as the traction of the wheels with the soil, are determined, taking into account the lateral force leading this unit down the slope. At the same time, as a stabilizing device, a micro-tiller is used, which makes it possible to pre-make a stabilizing groove for the wheels of the motor block. Further, using the developed power circuit, analytical expressions are compiled that allow us to numerically determine the structural and power parameters of a given aggregate, allowing it to stabilize its steady motion when working on a slope.*
KEY WORDS: *SMALL-SIZED AGRICULTURAL MACHINERY, MOTOBLOCK, SLOPE, STABILIZATION OF MOTION, EQUILIBRIUM EQUATIONS STABILITY.*

1. Introduction

The presence of slopes (for example, up to 12°) causes difficulties in the operation of any means of mechanization. When the slope of the slope is transverse with respect to the direction of movement of the slope above 5°, a lateral force arises that disrupts the stability of the running of this unit. This negatively affects the conduct of any agricultural operations. This phenomenon can be especially negative in the case of inter-row cultivation of soil, when the deviation of the unit from a given direction of motion leads to damage to a large number of plants. Small-sized machinery when working on slopes is less subjected to slipping than large, because due to the smaller mass there is less side power, which breaks the stability of the unit's travel. To completely eliminate this force, it is necessary to use stabilizing devices.

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications

There are various devices and mechanisms for stabilizing the direction of movement of the agricultural machines when working on slopes [2-4, 10-11]. Among these designs, one should single out those in which alignment of the unit's position with respect to the horizon on the transverse slope is provided, which eliminates the complete slipping of the unit when working on slopes. But in these constructions and, accordingly, in scientific works [1, 5] from this direction theoretical problems are not considered that are related to the implementation of the groove only under the upper wheel of the motor block (unit) that moves in a direction transverse to the slope.

2.2. Purpose of the study

Determination of the condition of balance of the wheels of the motor block and the force of their adhesion to the soil, a lateral force that disrupts the stability of the unit's travel.

3. Results and discussion

One of the promising devices, which solves many problems when the unit operates on slopes, is a microterreaser [2]. It completely removes the effect of the lateral component of the mass on the wheels of the tractor. A serious drawback of this scheme for the French patent is a significant increase in the strength of the unit's resistance, which causes a decrease in traction qualities of the tractor. In the reverse course, it becomes necessary to have circulating skimmers, which in turn requires the installation of revolving mechanisms for each skimmer separately, which will be controlled by the tractor operator. In another case, when the formation is turned up the slope, the resistance to rolling will increase. These requirements significantly complicate the design of the mechanism, which leads to a decrease in operational reliability and the scope of its application.

The question arises: is it possible to apply such a mechanism, in which only the upper wheel on the slope will move along the groove. We proposed a new device for stabilizing the direction of movement (ensuring the exchange rate stability) of the unit when working on slopes, which is described in [6-9].

This device can remove a hunk and, accordingly, perform a groove of such depth that the motoblock on a slope α will occupy a horizontal position. In this case, the action of the lateral component of the mass on the wheels of the motor block, which tries to move the motor-block down the slope, is completely eliminated. Nevertheless, to ensure rectilinear motion of the motoblock on the transverse slope, it is sufficient to remove the formation (to make a groove) of such a depth that the angle of the motor block relative to the slope is not equal to zero, but only slightly reduced by a certain amount.

Define lateral efforts on the dynamic performance of the motor block and justify the expediency of applying the mechanism of the proposed type. Let this device (its disk) fall off the layer down the slope α and make a groove (Fig. 1).

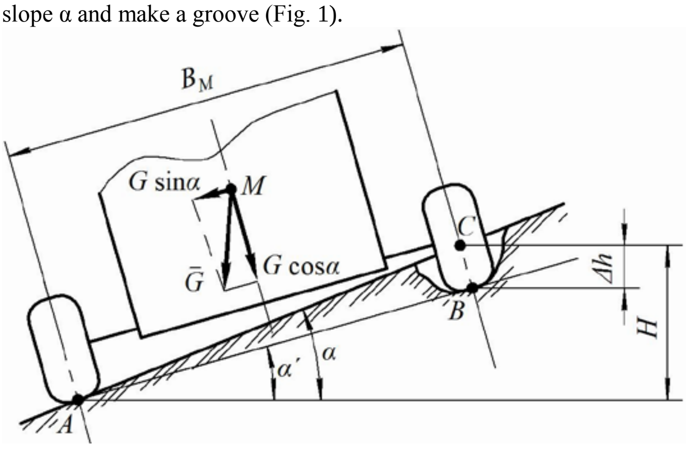

Fig. 1. – Scheme of location on the slope of the motor block with a stabilizing device

The upper wheel starts to move along the groove, and the motoblock with the wheel gauge of the wheels B_M occupies a new position on the transverse slope of the value α'.

Thus, the motoblock operates on the transverse slope α' by the value:

$$\alpha' = \arcsin\frac{H-\Delta h}{B}, \tag{1}$$

where H – vertical distance between the upper and lower wheels of the motor block on the slope α; $B_м$ – width of track of wheels of a motor-block; Δh – the preset depth of immersion in the ground of the device disk.

Due to the insignificant difference between the angles α and α' we assume that the point B (the point of contact of the wheel with the soil) is on the wheel axis.

Substitute the value of H in the equation (1) and after the transformations we get:

$$\alpha' = \arcsin\left(\sin\alpha - \frac{\Delta h}{B_м}\right). \tag{2}$$

Since $\alpha' < \alpha$, the main factor that causes the lower wheel and motoblock to deviate altogether from the given direction is reduced. At the same time, the lateral force does not act on the upper wheel, it is zero, since it moves in the groove. Consequently, the coupling mass is increased and the traction characteristics are increased.

Normal soil reactions of the upper and lower wheels, respectively:

$$\left.\begin{aligned} Z_1 &= \frac{1}{2}G, \\ Z_2 &= \frac{1}{2}G\cos\alpha'. \end{aligned}\right\} \tag{3}$$

Therefore, the upper wheel has the ability to develop a greater traction force than the lower one by the amount:

$$\left(Z_2 - Z_1\right)\varphi = \Delta P_к = \frac{1}{2}\varphi G\left(1 - \cos\alpha'\right), \tag{4}$$

where G – weight motoblock, which is on the wheels; φ – coefficient of lateral traction of the tire to the soil.

It is interesting to compare the indices of stability on the basis of an analysis of the equilibrium conditions of the wheels of the motor block with and without a stabilizing device.

The wheels of the motoblock, which are stationary on a terrain with a transverse slope α, will not slip sideways if the following condition is met:

$$\varphi G\cos\alpha \ge G\sin\alpha. \tag{5}$$

Because of the small difference, we take $\alpha \approx \alpha'$, then from Fig. 2 it can be seen that the equilibrium condition of the wheels of the motor block, which has a stabilizing device, will looks like:

$$\frac{1}{2}\varphi G\left(1 + \cos\alpha\right) \ge \frac{1}{2}G\sin\alpha,$$

$$\varphi\left(1 + \cos\alpha\right) \ge \sin\alpha. \tag{6}$$

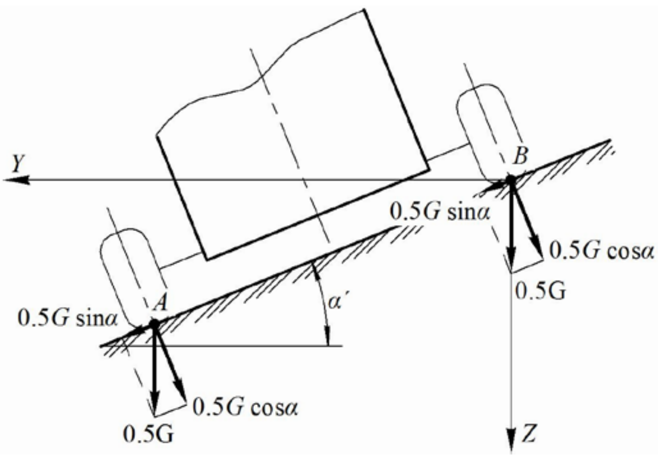

Fig. 2. – The scheme of forces that act on the wheels of the motorblock on the transverse slope

Comparison of equations (5) and (6) shows that the equilibrium conditions in the second case are significantly improved. In this case, the action of the lateral force $0.5G\cdot\sin\alpha$, which tries to move down the slope of the lower wheel, is transmitted to the upper wheel. We transfer the lateral force $0,5G\sin\alpha$ from the point A to the point B and decompose it into components:

$$Y = 0.5G\cdot\sin\alpha\cdot\cos\alpha, \tag{7}$$

$$Z = 0.5G\cdot\sin^2\alpha. \tag{8}$$

The first component causes slipping, the second – loads the upper wheel. Therefore, the total traction force of the wheels is:

$$R = 0.5G_2\cdot\varphi\cos\alpha + (0.5G_2 + 0.5G_2\cdot\sin^2\alpha)\varphi. \tag{9}$$

Thus, the equilibrium condition in the final version will be:

$$0.5G_2\,\varphi\,(1 + \cos\alpha + \sin^2\alpha) \ge 0.25G_2\cdot\sin2\alpha. \tag{10}$$

Comparing this equation with the condition of the balance of the wheels of the motoblock without a stabilizing device (from formula (5), we notice that the force that tries to move the motor-vehicle down the slope decreases more than twice. The reduction factor can be calculated by the equation:

$$n = \frac{G\sin\alpha}{\frac{1}{2}G\sin\alpha\cos\alpha} = \frac{2}{\cos\alpha}. \tag{11}$$

The force of traction of the wheels with the soil in the second case is greater by the value:

$$\Delta G = R - \varphi G\cdot\cos\alpha = 0.5G\,\varphi\,(1 - \cos\alpha + \sin^2\alpha).$$

And the magnification factor will be:

$$n_1 = \frac{R}{\varphi G\cdot\cos\alpha} = \frac{1}{2}\cdot\frac{\left[1+\left(1+\sin^2\alpha\right)\right]}{\cos\alpha}. \tag{12}$$

We have an improvement in the operation of the unit with a stabilizing device (the traction of the wheels with the soil increases, the lateral force decreases, which raises the stability of the stroke).

For example, the equilibrium condition on the slope of the slope of 12° (0.21 radians) by the formula (11) improves approximately by 2 times.

4. Conclusions

The above theoretical justification of the operation of the stabilizing device with the disc to the motor block at work on the transverse slopes makes it possible to determine the equilibrium conditions of the wheels of the motor block and the force of their adhesion to the soil, the lateral force that disrupts the stability of the unit's travel.

The above calculation technique can be used as a separate technique for carrying out important calculations and as a basis for further research on the operation of the whole unit.

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