Improvement of multifunctional technological machines when creating a geoinformation system

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Abstract. When creating methods and algorithms for analyzing transport characteristics and road transport infrastructure, it is necessary to develop new technologies that determine the improvement of the quality of the road fund of the Belgorod region.Improving the quality of the road fund directly depends on the organization of road construction and subsequent maintenance of highways. Road services and enterprises operating multifunctional equipment, in the conditions of digital transformation, are trying to introduce new technologies for the production of works that reduce the cycle time of the technological operation. One of such solutions is the use of quick-release connecting devices for multifunctional equipment. That allows you to reduce the amount of equipment used at the sites of road works.A refined method of static calculation of the stability assessment of a single-bucket excavator with the inclusion of a quick-release connecting device in the design of the working equipment is presented.

1 Introduction

The purpose of developing a methodology for creating a geoinformation system for the management, maintenance and repair of the regional road fund is to improve road safety, optimize the technology of construction of structural layers and increase the service life of highways. In 2023, on the basis of the regional state institution "Department of Public Roads and Transport of the Belgorod Region", an expert assessment of the technology for predicting probable places of occurrence of road accidents based on statistical and geoinformation analysis is being implemented and carried out [1]. An assessment of the effectiveness of practical measures for the device of technical means of organizing traffic on the territory of the Belgorod agglomeration is also carried out.

Using the developed algorithm for automated analysis of statistical data on accidents on experimental sections of public roads in the Belgorod agglomeration, photo-video cameras, traffic lights, road fences and road signs were installed. The research results are of an applied nature and can be used in the work of the traffic police service and executive

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authorities of the subjects of the Russian Federation and municipalities, road owners, organizations responsible for the maintenance of streets and roads [2].

When organizing practical events, it is necessary to use multifunctional technological machines that allow organizations responsible for the maintenance of streets and roads to reduce the amount of equipment used. The use of multifunctional technological machines and the creation of a "one-car park" allow us to develop a new technology that determines the improvement of the quality of the road fund of the Belgorod region [3-5].

In order to achieve economic efficiency when performing technological processes in construction, it is necessary to use complexes and individual machines with minimal specific reduced costs [6].

It is logical to conclude that it is possible to raise the question not only about the optimization of sets and complexes of machines, but also about the optimization of the designs of the machines themselves, including their working equipment

The performance of road construction machines is a basic indicator and the basis for the formation of other indicators.

Multifunctional technological equipment is expensive complex technical systems. The design of excavators and loaders provides for a built-in quick-coupling coupling device for instantaneous change of the working attachment body. The approximate use of mounted working equipment for a specially modified Model 950 Series II Custom Toolcarrier loader represented by more than twenty 20 types of replaceable attachments, including: a multipurpose bucket; buckets for light materials, for mineral fertilizers, with an upper clamp, for high emptying; forks for various purposes - for pallets, for logs and lumber, rod forks; various dumps - a blade with hydraulic rotation, a straight blade, a blade with manual rotation, blade with hydraulic rotation; hydraulic revolving plow, one-sided plow, manual revolving plow, V-shaped plow; asphalt milling cutter; hydraulic hammers.

This approach of the manufacturer will allow enterprises operating multifunctional equipment to reduce the number of machines involved in technological operations [7].

2 Materials and Methods

The study of the materials being moved will help determine the necessary attachments, special attention should be paid to the route of movement of the material, its type, as well as geometric and weight parameters (see Fig.1) [8].

One of the most important indicators determining the performance and safety of wheeled and tracked vehicles is their stability against overturning. In statics, this indicator characterizes the ability of the machine to maintain an equilibrium position under the influence of external loads, which are assumed to be constant. In dynamics, this indicator characterizes the ability of the machine not to tip over under the influence of variable forces that are a function of time and the position of the system [9].

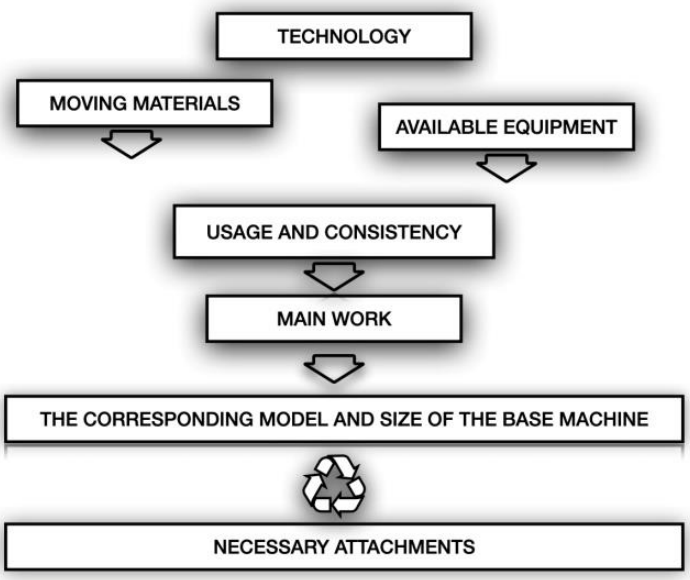

Fig. 1. Scheme of the work analysis method

The calculation of the weight of the counterweight is carried out from the condition of tilting the rotary platform forward and backward. For an excavator with a reverse shovel, the weight of the counterweight is calculated in case of tipping forward, taking into account that the filled bucket has come out of the face and the machine makes a turn for unloading (see Fig. 2).

When determining the weight of a counterweight for a technological machine with the inclusion of an additional intermediate node in the system of working equipment, it is determined by the equation of moments (1) relative to the point B:

$$G_{cw}^{f} = \frac{\left[G_{b+g}\left(l_6 - a\right) + G_{qd}\left(l_1 - a\right) + G_h\left(l_2 - a\right) + G_b\left(l_3 - a\right) - G_c\left(l_4 + a\right)\right]}{l_5 + a}, \qquad (1)$$

where G with indices – gravity of the bucket with the ground, quick-release connecting device, handle, boom, platform and counterweight, respectively;

a – the value of the distance from the tipping point to the conditional axis of rotation of the excavator platform;

$l_{1,\ldots 6}$ – the value of the distance from the line of action of the corresponding forces to the conditional axis of rotation of the excavator platform.

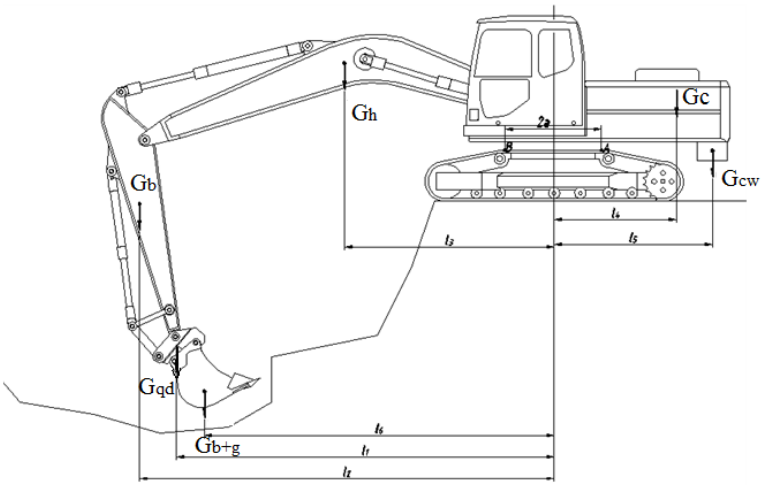

Fig. 2. Determination of the value of the counterweight of a multifunctional technological machinea quick-coupler in case of tipping forward.

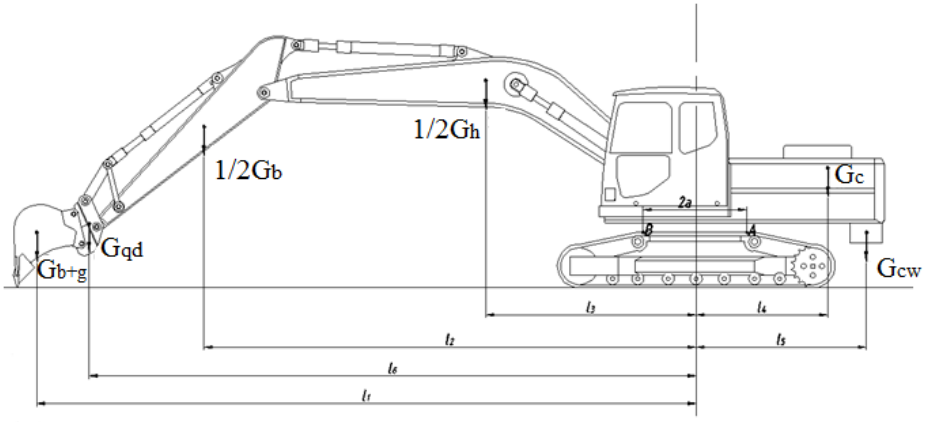

Fig. 3. Determination of the value of the counterweight of a multifunctional technological machine with a quick-coupler in case of tipping back.

In the case of overturning in the opposite direction, it is assumed that at the maximum reach of the handle, the empty bucket is lowered to the ground and its mass presses on the ground, and 1/2 of the weight of the boom and the handle act on the excavator platform (see Fig. 3). The mass of the counterweight is determined by the equation of moments (2) of forces relative to point A:

$$G_{cw}^{f} = \frac{\left[G_{b+g}\left(l_1 + a\right) + G_{qd}\left(l_6 + a\right) + \frac{1}{2}G_b\left(l_2 + a\right) + \frac{1}{2}G_h\left(l_3 + a\right) - G_c\left(l_4 - a\right)\right]}{l_5 - a}. \quad (2)$$

The actual weight of the counterweight is determined from the condition when tipping forward and backward:

$$G_{cw}^{f} < G_{cw} > G_{cw}^{b}.$$

When using a quick-coupler, the weight of the counterweight will increase by an amount:

- relative to point A $\frac{G_{кв}(l_1 - a)}{l_5 + a}$;

- relative to the point B $\frac{G_{qd}(l_6 + a)}{l_5 - a}$.

The stability of a single-bucket excavator is determined by the ratio of forces acting on the mounted working equipment and the design of the machine under the most unfavorable conditions of its operation. The stability coefficient is the ratio (3) of the total moment of the forces holding the car from tipping over to the total moment of the tipping forces:

$$K_s = \frac{\sum M_h}{\sum M_t} . \quad (3)$$

Checking the stability of a single-bucket excavator equipped with a reverse shovel is carried out for two conditions. In the first case, it is assumed that the bucket met an insurmountable obstacle at the exit from the face, and the condition is taken into account that at the same time all the engine power goes to lifting the boom with the handle. In the second case, the calculation is carried out when unloading sticky soil, assuming that the handle and bucket are at maximum reach [10].

For both cases, the stability coefficient is determined by the equation of equilibrium of the moments of forces that act on the excavator relative to point A.

The stability coefficient of the excavator is determined by the formula (3) from the equilibrium condition of the holding and tipping moments of all forces acting on the machine relative to A, while the total moment holding the excavator from tipping over relative to point A (4) will be equal to:

$$\sum M_s^A = G_{ch}a + G_{rp}(l_4 + a) + G_{cw}(l_5 + a), \quad (4)$$

and the total moment overturning the excavator relative to the same point will be equal to:

$$\sum M_t^A = (P_t \cos\Delta + P_t \sin\Delta) \cdot (l_7 - a) + G_{qd}(l_6 - a) + G_{b+g}(l_3 - a) + G_h(l_1 - a) + G_b(l_2 - a), \quad (5)$$

where $G_{ch}, G_{rp}, G_{cw}, G_{b+g}, G_{кqd}, G_h, G_b -$ the weight, respectively, of the chassis, the turntable, the counterweight, the bucket with the ground, the quick-release connecting device, the handle and the boom;

$P_t -$ the tangent component of the resistance to digging the soil.

Hence the coefficient of stability for an excavator with the use of BSU:

$$K_s = \frac{G_{ch}a + G_{rp}(l_4 + a) + G_{cw}(l_5 + a)}{(P_t \cos\Delta + P_t \sin\Delta) \cdot (l_7 - a) + G_{qd}(l_6 - a) + G_{b+g}(l_3 - a) + G_h(l_1 - a) + G_b(l_2 - a)} .$$

It is also necessary to check the stability of the machine in the transport position when it is moving at the maximum angle of ascent and descent. In both design cases, the working equipment is turned in the direction of movement, and the handle with the bucket is lowered vertically down, while the boom is tilted at an angle when lifting $50\ldots60^\circ$, and on the descent $35\ldots40^\circ$. In both cases, wind movement is also taken into account.

$W = p\sum F_i k_i$,

where $p -$ the specific wind load assumed to be equal to 0,25 кН/ m^2;

$F_i -$ windward area of the boom and cabin;

$k_i -$ the coefficient of uniformity of the design: for the cab $k_i = 1{,}0$.

The results of the static calculation of the excavator with the inclusion of an intermediate element in the working equipment system allow us to determine the change in the value of the counterweight, as well as the stability coefficient of the modified system.

3 Results and Discussion

When developing a methodology for creating a geoinformation system for the management, maintenance and repair of the regional road fund on the territory of the Belgorod agglomeration, goals are achieved, including improving road safety, optimizing the construction technology of structural layers and increasing the service life of highways by 2 times. It is expected to obtain a standard list of layers for transport facilities and transport infrastructure of the pilot site [11-12].

The use of multifunctional technological machines and the creation of a "one-car park" allow us to develop a new technology that determines the improvement of the quality of the road fund of the Belgorod region.

Analysis of the results of scientific research by leading scientists of the industry has shown that the main goal of research is to obtain the highest quality of work performed at the lowest cost, so ensuring economic efficiency [13-14].

The purpose of the static calculation is to determine the stability conditions of the excavator when an additional element between the handle and replaceable attachments is introduced into the design of the working equipment. After performing a stability check, it is necessary to calculate the working equipment [15].

The calculation of the working equipment of hydraulic excavators is carried out in two stages. At the first stage, the required power of the hydraulic pump is determined according to the specified performance and the working dimensions of the equipment specified in the technical specification. At the second stage, based on the selected drive power, the operability of the working equipment in various ground conditions and the forces acting on the working equipment at different positions of the bucket in the bottom are checked.

4 Conclusion

A refined method of static calculation of the stability assessment of a single-bucket excavator with the inclusion of a quick-release connecting device in the design of the working equipment is presented. The calculation of the forces acting on the elements of working equipment using a quick-release connecting device for an excavator with a typical working body – a bucket is given. The mathematical model for calculating the forces acting on the elements of the working equipment allows us to estimate the change in the magnitude of the forces when the quick-release connecting device is included in the design of the working equipment.

Improving the quality of the road fund directly depends on the organization of road construction and subsequent maintenance of highways. Road services and enterprises operating multifunctional equipment, in the conditions of digital transformation, are trying to introduce new technologies for the production of works that reduce the cycle time of the technological operation. One of such solutions is the use of quick-release connecting devices for multifunctional equipment. This reduces the amount of equipment used at the sites of road works.

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