INCREASING THE EFFICIENCY OF USE OF WHEELED TRACTORS WITH AN ARTICULATED FRAME FOR SECONDARY TILLAGE

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ARTICLE DETAILS

Article History:
Received 17 May 2018
Accepted 13 Jun 2018
Available online 18 July 2018

ABSTRACT

The article in hand describes the design and the results of testing of the new device for redistribution of trailing weight between tractor axles and an aggregated agricultural machine. The use of this device for redistribution of trailing weight between a mobile power unit (MPU) - a tractor - and an aggregated agricultural machine (APK 1.08 "Ermak") intended for secondary tillage is particularly important in the regions which are characterized as "areas of risk farming". The key feature of such zones is that the main agricultural works take place during the period when the soil has weak load bearing capacity due to high precipitation. The presence of a hard permafrost sublayer exacerbates the issue further. That said, with large areas to cultivate and limited time to perform the necessary agricultural works the use of high-speed high-power wheeled mobile power units is predetermined. It is necessary to note though that this type of tractors put high pressure on the soil, and with the increase of the traction power on the hook they slump down to the permafrost layer and lose their flotation capacity. The most appropriate solution for this problem in the described circumstances is redistribution of trailing weight between the mobile power unit and the agricultural machine. The article in hand aims to present the results of the experimental study of the mobile power unit (the tractor with an articulated frame Buhler Versatile 2425) and the agricultural machine APK - 1.08 "Ermak" with the integrated device for redistribution of trailing weight. The experiments established that redistribution of trailing weight allows to increase traction and adhesion in mobile power units, boost labor productivity, reduce the technogenic impact on the soil and preserve its fertility.

KEYWORDS

Wheeled Tractor, Articulated Frame, Trailing Weight, Redistribution, Technogenic Impact.

1. INTRODUCTION

Modern technologies for crop cultivation provide for the use of various mechanical means. The drive systems of this equipment affect the soil by puddling and panning it to a considerable depth, disrupting the structure and the moisture-air balance in the fertile layer [1,2]. Previous research on the topic of increase of efficiency of MPU uncovered that in order to decrease the number of passages through the field it is necessary to improve the traction-trailing properties of the unit. This allows for the expansion of the range of possible MPU aggregates with multifunctional machines. The researchers also came to conclusion that the improvement in traction-trailing properties of the mobile units, especially if they are used on soils with low load bearing capacity typical of the Amur Region, should involve lowering standard pressure of drive systems on the soil [3-6].

The main recognized methods of decreasing vertical pressure of the propulsions on the soils are as follows: the use of ribbed tires, twin wheels, track units, the uniform distribution of the mobile power unit weight along the axles, reduction in tire pressure, etc. [7-11]. In the Amur Region the high-powered wheeled tractors with an articulated frame are widely used. This is due to the fact that a great many fields in the land fund of the region have large cultivation areas and a running length. At the same time these tractors have a significant disadvantage — the basis weight of the construction is supported by the front wheels. When the load bearing capacity of soils is weak, the front wheels push up the upper layer of soil, slumping down to permafrost, which increases slipage and makes them lose their flotation capacity. They leave behind a significant track pit, which later needs to be further plowed and sealed. Besides, on following the track of the front propulsions, the rear driving wheels of the tractor can hardly implement their traction-trailing properties, as they move along a permafrost base layer with the decreased adhesion coefficient [12-14].

Reduction of standard pressure on the soil exerted by wheeled tractors is a well-favored topic for many researched around the world. Let's review the known ways of solving this issue. For instance, the author of proposes to reduce standard pressure of MPU on the soil by mounting additional wheels which allows for the increase in traction-trailing properties and labor productivity of the tractor and simultaneous decrease in technogenic impact on the soil [15]. The use of ribbed tires also helps to increase the contract area between the propulsions and the soil, reduce standard pressure on the soil, but in this case the agricultural company will require an additional set of tires which may be used for other works under the conditions of normal load bearing capacity of the soil [16-18].

According to the analysis of foreign and domestic research on the topic, the proposed methods of reducing standard pressure on the soil and improving traction-trailing properties of the tractors do not solve the issue for the tractors, the basis weight of which is supported by the front driving wheels, when they are used on soils with a hard permafrost sublayer. Consequently, the study in hand aims at finding new design-and-engineering solutions allowing to improve traction-trailing properties and decrease the technogenic impact on the soil. These are important factors contributing to the increase in efficiency of tractors and preservation of soil fertility. In consequence of the previous studies it has been established that the optimum and most prospective method of solving the above-described issue is rational redistribution of trailing weight between the wheels (propulsions) of the tractor and the agricultural machine [19-24].

2. MATERIAL AND METHODS

A good example of an optimal combination of a tractor with an articulated frame and a tillage aggregate is found in the utility model...
The results of experimental trials of MTA equipped with a trailing weight redistribution device in the unloaded front wheels mode.

The issue of redistribution of trailing weight between the tractor axles to improve maneuverability is discussed in detail in [21,26]. This topic was considered as part of the problem of increasing the longitudinal stability of a tractor with an articulated frame (a half-frame tractor). This is related to the fact that in recent years the amount of aggregated agricultural machines has increased due to the combination of a number of operations performed. When such a machine is moved to another place or set in transport mode, the longitudinal stability of the tractor deteriorates significantly. According to the experimental studies conducted by the authors, the partial redistribution of weight from the rear wheels to the front wheels helps to increase the longitudinal stability of MTA in such cases.

The article in hand provides a theoretical substantiation of redistribution of trailing weight from the front wheels of a half-frame tractor to the rear driving wheels. This is related to the fact that in the process of moving across a field with low bearing capacity of soil, the front wheels slump down to the permmafrost layer due to high standard pressure on the soil and lose their flotation capacity. In this case, the redistribution of trailing weight between the tractor axles allows for a reduction in standard pressure put by the front wheels on the soil, which reduces the probability of pushing through its upper layer. The analysis of the device operation was based on changes in the weight carried by the wheels of the rear half-frame and the weight carried by the front half-frame wheels.

Force response ($Y''_R$) and ($Y''_F$) in different modes of device operation are shown on Figures 4 and 5 in the form of dependencies between the change in the distance ($a''_y$) from the point of application of the weight load on the rear driving axle of the MPU to the vertical projection of the center of mass of the MPU and the active force caused by the impact of the hydraulic cylinder ($P''_B$).

The trials of MTA for secondary tillage equipped with the said redistribution device in the mode when the front driving wheels of the tractor were unloaded, and part of the trailing weight was transferred to the rear wheels at selected agricultural enterprises have proved the validity and correctness of the system algorithm for the selection of devices for the redistribution of trailing weight and the need for their application in the plant cultivation technology [19].

The key feature of the proposed device is its ability to redistribute trailing weight between the tractor axles, as well as between the power unit and the agricultural machine, via a hydraulic power cylinder impacting the hitch tongue, the frame of the agricultural machine and the towing device of the tractor, in order to maintain optimal deepening for the cultivating implements, increase the operational comfort and decrease time expenditures when using a tillage machine. This method also provides for the decrease in cost and metal intensity of this type of machinery, for the improvement of quality of secondary tillage, as well as for reduction of energy costs of machine-tractor aggregates. The idea behind the invention is that such a device allows to adjust the weight by redistributing it between the tractor axles and the tillage machine.

The results of experimental trials of MTA equipped with a trailing weight redistribution device in the unloaded front wheels mode.

3. RESULTS

The results of experimental trials of MTA equipped with a trailing weight redistribution device in the unloaded front wheels mode.

One more way to reduce standard pressure on soil is partial redistribution of the weight of the tractor to the tillage machine in order to increase the soil tillage quality. Under normal conditions, this requires the use of additional ballasting (changeable loads) which improves the tillage depth and, in turn, leads to the increase in the weight of the implement (the machine) and the technogenic impact on the soil. The installation of the proposed device allows to use part of the weight of the mobile power unit (the tractor) for the same purpose.

The redistribution process under these circumstances is presented in more detail on Figure 6, which clearly depicts the dependency of change in the vertical load transferred to the tillage machine $N$ on the additional force created by the hydraulic cylinder ($P$) and the angle of the application of this force ($\alpha$). The obtained results allow to conclude that the allow us to conclude that the maximum value of force response $N''$ in the MPU towing device is achieved with the simultaneous change of factors along the axes $P$ and $\alpha$. In this case, both the direct and the inverse dependency between the factors can be observed, since the increase in the value of force response $N$ in the MPU towing device can be caused either by a decrease in the load angle $\alpha$ or by an increase in the transferred load $P$.

![Figure 6: Dependency of change in the value of $(N')$ on the applied force $(P')$ and the load angle $(\alpha)$](image)

5. THE RESULTS OF THE EXPERIMENTAL TRIALS OF THE DEVICE IN THE MODE OF PARTIAL TRANSFERRING OF TRAILING WEIGHT FROM THE TILLAGE IMPLEMENT TO THE REAR WHEELS OF THE TRACTOR

In the Amur Region, secondary tillage is considered one of the most difficult and energy-consuming operations, which constantly requires a short-term increase in traction-trailing properties of the power unit. It can be achieved by partial redistribution of the tillage machine weight to the tractor. The proposed device can solve this task, which is clearly supported by the results of experimental trials presented in a graphical form on Figure 7.

When analyzing the dependency of force response in the front part (section) of the agricultural machine at its point of attachment $Y''$, on such factors as the transferred load $P$ and the load angle $\alpha$, one can note that if the value of the transferred load is constant, the change in the load angle $\alpha$ does not significantly affect the value of force response in the front part (sections) of the machine at its point of attachment $Y''$. The redistribution process under these circumstances is presented in more detail on Figure 6, which clearly depicts the dependency of change in the vertical load transferred to the tillage machine $N$ on the additional force created by the hydraulic cylinder ($P$) and the angle of the application of this force ($\alpha$). The obtained results allow to conclude that the allow us to conclude that the maximum value of force response $N''$ in the MPU towing device is achieved with the simultaneous change of factors along the axes $P$ and $\alpha$. In this case, both the direct and the inverse dependency between the factors can be observed, since the increase in the value of force response $N$ in the MPU towing device can be caused either by a decrease in the load angle $\alpha$ or by an increase in the transferred load $P$.

![Figure 7: Graph of value $(Y'n)$ variance in the mode of loading the power unit / unloading the tillage machine, showing the dependency of the value on the additional applied force $(P)$ and the angle $(\alpha)$ of its application](image)

6. CONCLUSION

Based on the above, we can conclude that the use of the proposed device allows to redistribute the trailing weight between the axes of the power unit and perform strength loading (unloading) of the soil cultivating agricultural implements (machines). The suggested method helps to regulate traction-trailing properties of the tractor and thus contributes to the reduction in energy costs and technogenic impact on the soil due to optimal weight distribution. Consequently, the proposed device is a highly efficient design-and-engineering solution that implements original ideas and has a proven scientific novelty. It provides for the efficient and rational use of the trailing weight of the machine-tractor aggregate.

The results of the conducted experimental trials and empirical research have been reviewed, approved and recommended for application in the plant cultivation technology by the expert committee of the Arkhara and Tambov Districts seeking to introduce latest scientific and technical developments and best practices into agribusiness. They were implemented by ZAO (NP) “Agrofirma “Partizan”,” OAO “Leninskoye”, ООО “SERVIS-AGRO”, ООО “Soyuz”, OAO “Dimskoe”, ООО “Krasnaya zvezda”, Farm Enterprise “Zarechnoye” and at several other agricultural enterprises.

The implementation of the obtained results in the production allowed to improve the flotation capacity and maneuverability of the agricultural aggregate, decrease the technogenic impact on the soil, increase the safety of operation and the efficiency of wheeled tractors on aggregation, which resulted in slashing the energy costs and increasing the economic effect of their application in agriculture, and also marked out directions for sustainable use and long-term conservation of the fertility of soil horizons, which is especially important for the environment protection and modern natural resource management.

REFERENCE


