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Decreasing the Technogenic Impact on the Soil and Increasing the Efficiency of Use of Wheeled Combined Harvesters

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Abstract: One of the peculiarities of lands in the Amur Region is the presence of a solid underlying layer in the form of a clay bed which is located at the depth of 0.3-0.35 m. Heavy precipitation during the harvesting period creates a situation when the upper layer of the soil is quickly saturated with moisture but the solid underlying layer prevents this moisture from being distributed to the deep. As a result, the load-bearing capacity of the oversaturated upper layer declines sharply and it is unable to hold the weight of the harvester. When working on soils with low load-bearing capacity, the wheels of the harvester (combine) which are more loaded slump down to the solid underlying clay layer during the movement and leave a deep track pit thus increasing the technogenic impact on the soil and energy costs. This also, hinders the further operation of the machine. Previous studies on the topic have made it possible to propose a promising method to solve this problem which involves redistribution of the weight load between the wheels of the harvester to even out the pressure on the soil caused by the machine. The study in hand describes the design and lists the results of experimental testing of a new device regulating the weight load of a combine harvester during the harvesting period. The utilization of the proposed device will allow redistributing the weight of the harvester between its wheels, to decrease the normal pressure of the machine on the soil and thus, increase the efficiency of its use.

Key words: Combine harvester, weight, soil, technogenic impact, harvesting, energy costs, efficiency

INTRODUCTION

The technology of harvesting crops provides for the use of various machines. Their ground driving systems compact the soil at a considerable depth. In order to decrease this impact, it is necessary to decrease the pressure of propulsors on the soil. At present, this task is completed by using the following methods: the use of arch tires and tires with the increased diameter, mounting of twin wheels, implementation of semi-crawler units, rational redistribution of weight along the axles, reduction of tire pressure and other (Rusanov, 1997; Emelyanov, 2007).

For harvesting of crops in the Amur Region, the enterprises widely use modern high-efficiency harvesting units including wheeled grain combine harvesters of the following brands: KZS-1218-40; Acros-530; Vector-410; Class tucano-430; Claas tucano-470; Claas mega-350. Also, proper allowance must be made for the fact that the cultivation areas of the region usually have a large furrow length which is why in order to decrease the technogenic impact of the ground drive systems of the harvesters and other machines on the oversaturated soil, the grain tank of the combine must provide for collecting the whole harvest in the processed strip from the beginning of the furrow until its end.

At the same time, it must be noted that as per the wheeled combine harvester design, the main weight is put on the front driving wheels which increases the pressure of the propulsors on the soil, in particular when the machine stops. On the basis of the above, we can conclude that the search for the solution for the problem of reducing the technogenic impact on the soil produced by harvesting equipment, especially for soils with low load-bearing capacity whichare typical of the Amur Region should follow the path of uniform distribution of weight between the wheels of the harvester.

Reduction of normal pressure on the soil exerted by wheeled combine harvesters is a well-favored topic for many researchers around the world. There are several proposed methods for solving this issue (Shitov *et al*., 2013; Tikhonchuk *et al*., 2013; Bekker and Collins, 1972). For instance, studies (Burt and Bailey, 1975; Dwyer and Pearson, 1976; Nielsen *et al*., 1977) seek to relieve the normal pressure on the soil by mounting additional or twin wheels on the harvester which provide for a

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simultaneous decrease in the pressure and the technogenic impact as well as for an increase in performance.

The conducted analysis of Foreign and domestic scientific works shows that the suggested methods for decreasing the normal pressure of the propulsions and the technogenic impact on the soil won't solve the problem for the soil conditions of the Amur Region when the enterprises use combine harvesters with the main weight put on the front wheels and operate them on soils with a low load-bearing capacity and the presence of a solid underlying clay layer.

Consequently, the purpose of this study is searching and implementing new design and engineering solutions allowing to decrease the normal pressure on soil and eliminate the technogenic impact of the running wheel system of the combine harvester. These are important factors contributing to the increase in efficiency of harvesting equipment, preservation of soil fertility and cost-effective use of agricultural resources.

In consequence of the previous studies (Rusanov, 1997; Emelyanov, 2007; Shchitov, 2013; Bunt and Baily, 1975; Rusanov, 1997) it has been established that the most prospective method of solving the above-described issue is the optimal redistribution of weight between the wheels of the used machine.

MATERIALS AND METHODS

The example of an optimal combination of a combine harvester and a device for redistribution of weight between the wheels is presented in the design of a device for position control and decreasing of pressure on the soil of the control system the steering axle of the wheeled grain combine harvester (Russian Utility Patent No. 2546895) (Kuznetsov, 2015). Figure 1 shows the installation scheme for this device.

The proposed device is formed as a structure composed of a loading mechanism containing three flat multi-leaf springs with lugs, a cylinder hollow roller with a central axle made from composite materials and a power hydraulic cylinder. It is mounted on the beam of the steering axle and the combine body frame with the help of brackets with a horizontal hinge. The lugs of two springs are put into the hinge of the bracket on the steering axle beam, one of them is inserted into the central axle of the cylinder hollow roller via the consequent lug. One of the lugs of the third spring is also installed there, so that, the consequent lug of the third spring is attached to the lug of the second spring by a bolt connection in the forked guide of the power hydraulic cylinder fixed in the hinged bracket on the machine body.

The testing of the combine harvester equipped with the device for weight redistribution was carried out in accordance with the recommended general and particular methods using specialized programs for mathematical calculation, experimental simulation and regression analysis methods (Shchitov, 2014a, b; Shchitov and Kriuvca, 2014; Gondzio and Terlaky, 1996). The data obtained during the experiment was processed via known methods of mathematical statistics with the use of information technologies.

The combine harvester was equipped with the programmable GPS/GSM controller (GPS receiver) for collecting, storing and transmission of route data (time-dependent GPS measurements) and information about the operation of the machine (fuel consumption rate, engine working conditions, etc.). In addition, we measured the weight that was put and redistributed between the wheels as well as the physical and mechanical characteristics of the soil. To measure the above parameters, specialized instruments and apparatus were used.

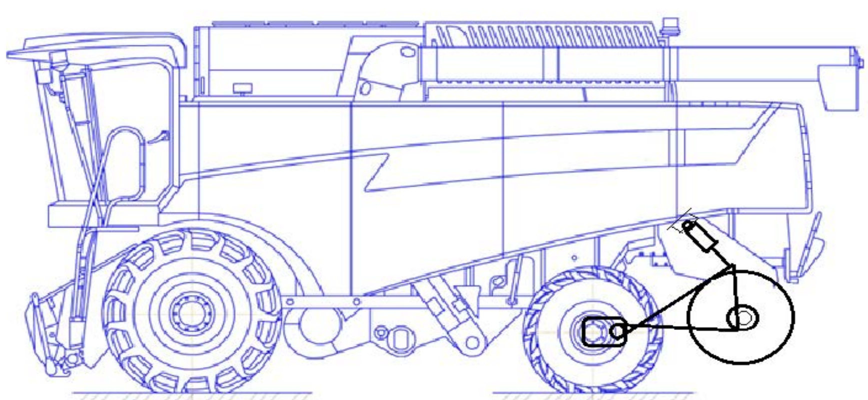

Fig. 1: The installation scheme of a combine harvester equipped with a device for weight redistribution

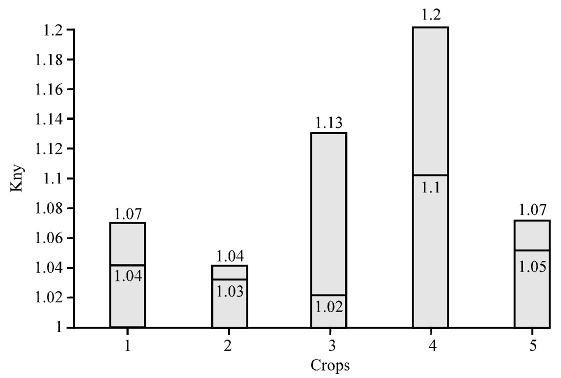

Fig. 2: Grain combine harvesters by soil compaction rate during the harvesting of crops; 1); K3C 812; 2) Claas mega 350; 3) Vector 410; 4) Acros 530 and 5) KZS-1218-40

RESULTS AND DISCUSSION

The results of testing combine harvesters equipped with a trailing weight distribution device. The trials of the combine harvesters with the trailing weight distribution device conducted 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 crop harvesting technology.

Studies by Shchitov (2013, 2014a, b) and Kidyaeva (2013) provide the theoretical justification of the efficiency of use of grain combine harvesters in the crop harvesting technology. The results of the experimental trials aimed at evaluation of the technogenic impact of the ground drive system on the soil conducted with the harvesters equipped by the weight redistribution device are presented in the form of a diagram in Fig. 2.

The analysis of the results of the studies and the processing of the necessary calculations showed that the smallest soil compaction rate of 1.07 was found in the claas mega 350 harvester and the largest value was demonstrated by acros 530-1.2. It has also, been established that the use of the weight redistribution device allowed to decrease those compaction rate values down to 1.03 and 1.1 accordingly. Similar results were obtained for other combine harvesters.

The increase in soil density ultimately leads to an increase in the energy consumption of the harvesting machine which is clearly shown in the form of a diagram in Fig. 3.

Overall crop losses behind the combine have equally significant impact on the increase in energy costs. Based

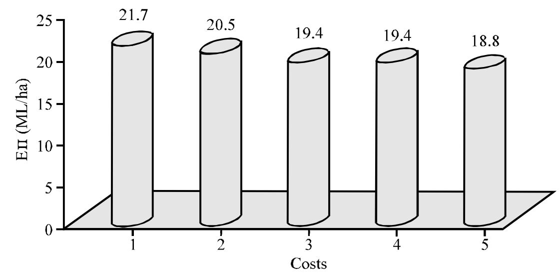

Fig. 3: Grain combine harvesters by full energy costs resulting from crop lntosses due to soil compaction during soybean harvesting: 1) Acros 530; 2) Vector 410; 3) KZS 1218-40; 4) KZS 812 and 5) Claas Mega 350

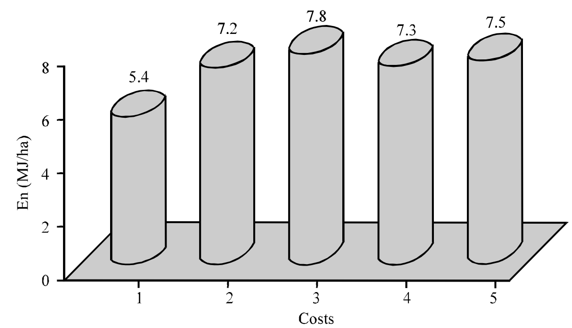

Fig. 4: Grain combine harvesters by full energy costs resulting from total crop losses behind the combine during harvesting: 1) Acros 530; 2) Vector 410; 3) KZS 1218-40; 4) KZS 812; 5) Claas Mega 350

on the studies, we calculated the total energy costs resulting from total crop losses for each of the combine harvesters under comparison. The results are shown in the form of a diagram in Fig. 4.

Having evaluated the total energy costs resulting from overall crop losses for the selected grain combine harvesters, it can be noted that the greatest energy expenditure of 7.87 MJ/ha was demonstrated by the KZS 1218-40 combine harvester and the smallest value of 5.4 was obtained while operating acros 530 MJ/ha. The results of the study aimed at determining the significance factor of energy costs resulting from the crop losses are presented in Fig. 5.

According to the results obtained, the smallest significance factor of energy costs resulting from the crop losses was found in KZS 812 and claas mega 350 harvesters. The biggest value of 40 was demonstrated by the vector 410 and KZS 1218 machines. It has also been established that the total energy consumption is greatly influenced by the direct energy costs.

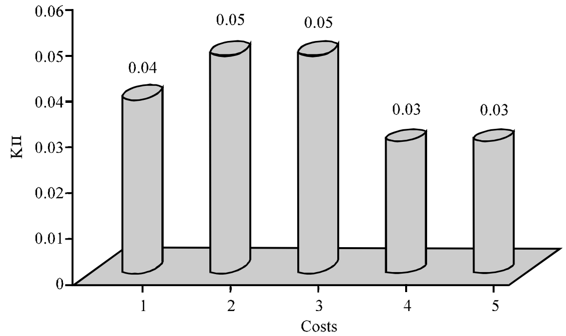

Fig. 5: Significance factors of energy costs resulting fromcrop losses during soybean harvesting: 1) Acros 530; 2) Vector 410; 3) KZS 1218-40; 4) KZS 812 and 5) Claas Mega 350

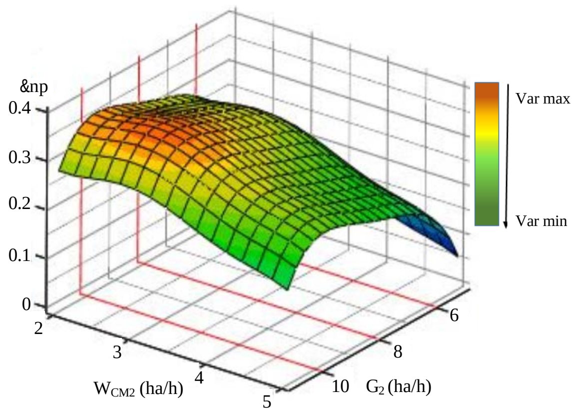

Fig. 6: The variation of the weighting factor of the direct energy costs of the combine harvesters of different brands as influenced jointly by the fuel consumption rate and the performance during the crop harvesting

The fuel and energy evaluation conducted in the course of the study suggests that the total energy expenditures are greatly influenced by the direct energy costs, the weighting factor of which varies from 0.62-0.73. It has been established that this factor is most impacted by fuel consumption rate and performance. When studying the joint impact of two factors-the fuel consumption and the performance of combine harvesters of various brands, both stock models and equipped with a device for the redistribution of weight between the wheels we have found that fuel consumption is a more important factor in the variation of direct energy consumption (Fig. 6).

The least weighting factor was found in the combine harvesters with the fuel consumption rate between 6 and 8 L/ha and the performance of 4-5 ha/h. The biggest weighting factor was demonstrated by the machines with the fuel consumption rate between 8 and 10 L/ha and the performance of 2-4 ha/h.

As per the obtained results, we may conclude that the use of the device for redistribution of weight between the wheels of the tractor decreases the weighting factor of the direct energy costs by 15, ..., 20% as compared with stock combine harvesters. This undoubtedly confirms the high efficiency of the proposed solution, justifying its practical and industrial prospects in comparison with previous studies (Emelyanov, 2007; Bekker and Collins, 1972; Rusanov, 1997).

CONCLUSION

Based on the above-described data obtained during the study, we can conclude that the use of combine harvesters equipped with a device for redistributing weight between the wheels of the machine will help to decrease the normal pressure and the the resulting technogenic impact of the propulsors on the soil. Consequently, the proposed device for the redistribution of weight between the wheels of the combine is a highly efficient design implementing original ideas and a construction novelty intended for decreasing the technogenic impact on the soil. The materials of the research are implemented in the crop harvesting technology used by OAO “Dimskoye” (Tambovskiy District), ZAO (NP) “Agrofirm Partizan” (Tambovskiy District), OOO “Priamurye” (Tambovskiy District) and the communal farm “Luch” (Ivanovskiy District). These administrative areas are located in the Southeastern agricultural zone of the Amur Region; Their edaphoclimatic conditions are comparable. The manufacturing application of the obtained results allowed decreasing of energy costs per product unit.

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