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Pressure on the Soil of the Front Wheels of Tractors with Different Wheel Formulas

Akhmetov Adilbek Agabekovich, Akhmedov Sherzodbek Anvarhon ogli, Botirov Ravshan Mahkam ogli, Kambarova Dilfuza Usmonaliyevna

Abstract: ***An increase in the power of wheeled tractors led to an increase in their mass and the mass of machine tools aggregated with them, which led to negative anthropogenic impacts on the soil, especially of tractors with a wheel formula of 3K2. Experiments have shown that the pressure created by the front wheel on the root layer on the soil of the TTZ-811 tractor with the 3K2 wheel formula is on average 4.5-9.5 % higher than that of the TTZ-1033 tractor with the 4K2 wheel formula. Reducing the sealing effect of the front wheels on the soil is possible by replacing the tractor with the wheel formula 3K2 with a tractor with the wheel formula 4K2, as well as by reducing the air pressure in the tire.***

Key words: tractor, wheel formula, soil compaction, pressure, tire.

I. INTRODUCTION

As the tractor power increases, its mass and the mass of machine tools aggregated with it increase, which leads to an increase in the negative technogenic impact of the machine-tractor unit on the soil. This effect on the soil is especially noticeable in tractors with a wheel formula of 3K2, in which the load on the front wheel reaches a value higher than the permissible one. As a result, in those areas where the front wheel passed, the soil density is 1.5 or more g / cm3, which is undesirable. Since, according to many researchers [1, 2], the optimal soil density for cultivating grain and row crops should not exceed 1.2-1.3 g / cm3.

Excessive compaction of the soil reduces the possibility of the plant absorbing nutrients from the soil and thereby slows down the development of both the root system and the plant as a whole, which affects the yield of the cultivated crop [3].Studies carried out at the Design Technological Center for Agricultural Machinary (DTCAM) showed [4-5] that tractors with a wheel formula of 3K2 are characterized by increased negative anthropogenic impacts on the soil. This is due, on the one hand, to an increased coefficient of coverage with wheel marks (three tracks instead of two), and on the other, a characteristic high sealing effect from vertical loads distributed on three wheels instead of four.

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***** Correspondence Author
Akhmetov Adilbek Agabekovich*, Doctor of Technical Sciences, Professor, Tashkent State Technical University named after I. Karimov, Republic of Uzbekistan E-mail: tractor-v@mail.ru
Akhmedov Sherzodbek Anvarhon ogli, doc Phil. (PhD), General Director of Design and Technology Center for Agricultural Machinary, LLC, Republic of Uzbekistan E-mail: myuzdoc@gmail.com
Botirov Ravshan Mahkam ogli, doctoral student, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Republic of Uzbekistan E-mail:uzbek0091@gmail.com
Kambarova Dilfuza Usmonaliyevna, Assistant, Tashkent State Technical University I. Karimova, Republic of Uzbekistan E-mail: kdu.317@mail.ru

Considering the fact that the degree of soil compaction by wheeled tractors depends on their weight, wheel formula and machine tools mounted with it [6–9], studies at the DTCAM conducted to study the influence of the tractor wheel formula on soil compaction. Moreover, taking into account the tractors with wheel formulas 3K2 and 4K2 available in the agro-industrial complex, they were taken as objects of study. With the exception of clearance, the main difference between these tractors in the number of front wheels and the load they perceive. Therefore, studies have examined the impact on the ground of the front wheel having the same tire at different air pressures therein.

The purpose of the study - the study of the influence of formula wheel and air pressure of a tire on the tractor front wheel pressure on the ground.

Materials and methods. The experiments were carried out on a typical gray soil of long-term irrigation. Humidity and hardness of the soil in the root-inhabited layer (0-20 cm) were 15.3% and 1.67 MPa. In the experiments, the TTZ-80.11 tractors with the wheel formula 3K2 and TTZ-1033 with the wheel formula 4K2 were compared (Fig. 1).

The pressure of the wheel mover on the soil was determined in accordance with GOST 26953-86 and GOST 7463-2003. In this case, the contact area of the tire of the wheel with the surface was determined by a well-known method, i.e. by the area of the spots of tire contact with the surface. The area of the contact spots of the tire tires of the tested tractors was determined in accordance with the above standards and based on them, the pressure values on the soil of the front wheels of the tractors were determined.

a) *b)*

Fig. 1. Tractors TTZ-80.11 with a wheel formula 3K2 (a) and TTZ-1033 with a wheel formula 4K2 (b)

To measure the pressure of the front wheels of the tractor on the soil, TAS 607 type force sensors were used with special manufactured nozzles that receive pressure from the wheel mover through the soil and transmit it to the sensor load cell. The output signal from the sensor via a connecting cable was transmitted to the amplifier and after amplification to the recording equipment (Fig. 2).

The study determined the maximum and average front wheel pressure on the soil. In this case, the maximum pressure was measured along the axis of symmetry, and the average pressure was measured along the width of the front wheel tire.

Fig. 2. Equipment for measuring pressure of a wheel mover on the soil

The maximum and average pressure created by the front wheels of the tested tractors on the soil was measured at a depth of habitat of the root system of growth (0-20 cm). To do this, first cut the trench to a depth greater than the depth of the sensors, and then cut a recess with a height equal to the height of the sensors on the wall of the trench at the level of the pressure measurement depth (Fig. 3). Sensors were installed in these grooves and a trench with installed sensors was filled with soil and rolled slightly until a homogeneous addition was obtained.

When measuring the maximum pressure of the front wheel of the tractor on the soil, the sensors were installed along the symmetry axis of the front wheel to the depth of the root layer (0-20 cm) of the soil.

When measuring the average pressure of the front wheel of the tractor on the soil, the sensors were installed along the width of the front wheel tire in one row to the depth of the root layer of the soil.

Fig. 3. Installation of sensors in one row across the width of the front tire to the depth of the root layer of the soil

The values of soil pressures perceived by the sensors were determined when the front wheel of the tractor passed along the site with the sensors installed so that the longitudinal lines of the front wheels coincided with the axially marked line.

Pressure measurements were carried out when the tractor was moving in idle mode, i.e. no load on the hook Pcr = 0 when its working speeds.

Strain gauges were calibrated in the tensometric laboratory of the Scientific Research Institute of Mechanization and Electrification of Agriculture, and the equipment was tested in the field on the fields of Testing of agricultural machinery and technology center.

II. RESULT AND DISCUSSION

In the study, by type of tractor, the air pressure in the front tire was varied from 0.12 to 0.22 MPa. This is explained by the following considerations.

An analysis of the results of research by many authors shows that the pressure of the front wheel on the soil depends on the magnitude of the load Gп on it and the contact area of the tire with the soil. Moreover, the contact area of the wheel tire with the soil depends on the load on the front wheel Gп and the air pressure in the tire ρw, which directly affects the deflection of the wheel tire.

The studies showed that the area Sпл of the flat contact zone of the front wheel tire with the soil has the shape of an ellipse with half axes a and b (Fig. 4) and it is determined by the well-known expression

$$S_{пл} = \pi ab. \quad (1)$$

Determining the value of the semiaxes a and b of the ellipse, i.e.

$$a = \sqrt{2Rh_ш - h_ш^2}, \quad (2)$$

and

$$b = \sqrt{2R_{пр}h_ш - h_ш^2}, \quad (3)$$

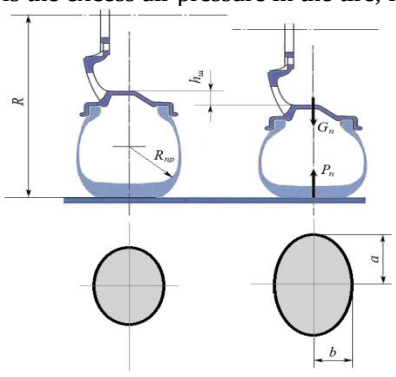
where R is the free radius of the wheel, m; Rпр - tire tread radius, m; hш - normal tire deformation in the flat zone of contact of the wheel with the soil, m, we find the area Sпл of the flat zone of contact of the wheel with the soil

$$S_{пл} = \pi\, h_ш \sqrt{(2R - h_ш)(2R_{пр} - h_ш)} \quad (4)$$

When the load Gp acting from the tractor to the front wheel and the soil reaction Pn to it, according to [10], we can take a linear relationship between Gp and hш, described by the Heideckel formula

$$h_ш = \frac{G_n}{2\pi\rho_w\sqrt{RR_{пр}}}, \quad (5)$$

where ρw is the excess air pressure in the tire, MPa.



а) *б)*

Fig. 4. The scheme for determining the area of the flat zone of contact with the soil of the front tire: а)

- unloaded and b) - the loaded position of the front wheel

Expressions (4) and (5) show that the contact area of the wheel tire with the soil, which receives a certain load Gп, depends on the free radius of the wheel, the radius of the tread and the internal air pressure in the tire. As is known for a particular tire size and wheel parameters, the free radius of the wheel and the radius of the tire tread are constant, while the air pressure in the tire can be changed as necessary. Therefore, experimental studies were conducted at various air pressures in the tire, i.e. at 0.12; 0.17 and 0.22 MPa.

Table 1 Front wheel pressure on soil in comparison tractors

TTZ-1033 4K2 Wheel Tractor			
Front tire pressure, MPa	Front wheel tire contact area, mm2	Front wheel pressure on the soil (tire sizes 9.00-16, load 8701.5 N), kPa	
		Mean value	Maximal value
0,12	50666	112,2	168,4
0,17	48400	138,4	207,6
0,22	41566	161,1	241,7
TZ-811 tractor with 3K2 wheel formula			
Front tire pressure, MPa	Front wheel tire contact area, mm2	Front wheel pressure on the soil (tire sizes 9.00-16, load 8701.5 N), kPa	
		Mean value	Maximal value
0,12	83566	122,8	184,2
0,17	73566	139,5	209,25
0,22	60966	168,3	252,4

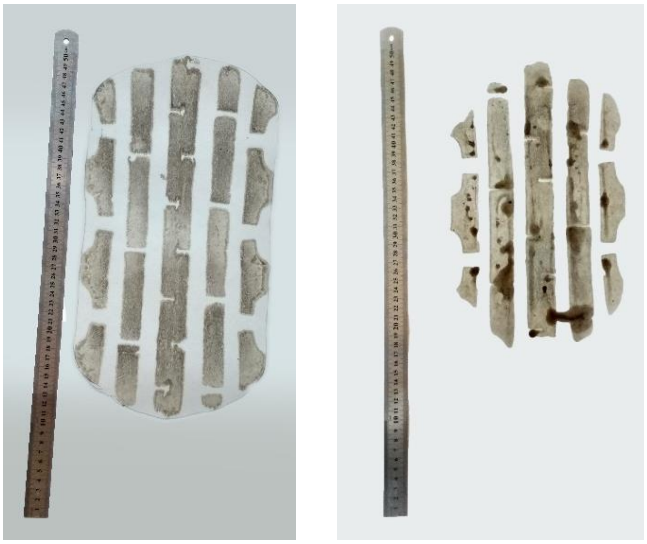
III. DISCUSSION

As a result of the experiments, an extensive material was obtained characterizing the pressure of the front wheel of the tractor on the soil depending on the air pressure in the tire and the area of contact with the soil of the front wheel tire (Table 1).

A comparative analysis shows that at the same air pressure in the tire, the area of the contact spot of the front wheel tire of the TTZ-811 tractor with the wheel formula 3K2 is larger than that of the TTZ-1033 with the wheel formula 4K2. But, despite the large contact patch area on the TTZ-811 tractor, the front wheel pressure on the soil is greater than that on the TTZ-1033 tractor by an average of 4.5-9.5%.

The experiments showed that the average value of the front wheel pressure on the soil within the tire air pressure of 0.12-0.22 MPa for the TTZ-811 tractor ranges from 122.8 kPa to 168.3 kPa, while for the TTZ- tractor 1033 it ranges from 112.2 kPa to 161.1 kPa. The maximum pressure of the front wheel on the soil for the TTZ-811 and TTZ-1033 tractors was from 184.2 kPa to 252.4 kPa and from 168.4 kPa to 241.7 kPa, respectively.

Table 1 shows the value of the maximum pressure on the soil of the front wheel, taking into account amendments, calculated by measuring the areas of the spots of the front wheel contacts of the tested tractors, based on the presented photographs of the wheel prints (Fig. 5).



a) *b)*

Fig. 5. The type of contact spots of the tires of the front wheels of the TTZ-811 tractors (a) and TTZ-1033 (b)

A comparative analysis of the data obtained during the study showed that the pressure exerted by the front wheel on the soil of a TTZ-811 tractor with a wheel formula of 3K2 is greater than that of a TTZ-1033 tractor with a wheel formula of 4K2.

IV. CONCLUSION

With a constant load on the front wheel, its sealing effect on the soil depends on the free radius of the wheel, the radius of the tread of the tire and the internal air pressure in it. The pressure generated by the front wheel on the root layer on the soil of a TTZ-811 tractor with a 3K2 wheel arrangement is greater than that of a TTZ-1033 tractor with a 4K2 wheel arrangement. Reducing the sealing effect of the front wheels on the soil is possible by replacing the tractor with the wheel formula 3K2 with a tractor with the wheel formula 4K2, as well as by reducing the air pressure in the tire.

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AUTHORS PROFILE

Akhmetov Adilbek Agabekovich, Doctor of Technical Sciences, Professor of Tashkent State Technical University named after I. Karimov of the Republic of Uzbekistan

Akhmedov Sherzod Anvarkhon ugli, doc Phil. (PhD), General Director of Design and Technology Center for Agricultural Machinary, LLC, Republic of Uzbekistan

Botirov Ravshan Mahkam ogli, doctoral student, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Republic of Uzbekistan

Kambarova Dilfuza Usmonaliyevna, Assistant, Tashkent State Technical University I. Karimova, Republic of Uzbekistan