AIR PRESSURE IN TIRES EFFECTS ON SLIPPAGE OF TRACTORS

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Abstract. Traction features of the tractor depend on the dynamic rates of the engine and transmission parameters. The traction features of the tractor depend greatly on the driving wheel exploitation characteristics, the physical-mechanical properties of the soil, and on the interaction of the driving wheels and the soil. By reference to the tests it was estimated that in the soil, if tractor wheels transmit driving force, they certainly slip. To reach maximum efficiency in production works, tractors are loaded by as high drawbar pull as possible. The consequence of it, quite often, is that the slippage of the driving wheels grows to the limit that is not allowed. There are various ways to reduce slippage. One way is to increase the contact area between the tires and the supporting surface. This is achieved by increasing the vertical wheel load and decreasing the pressure in the tires. There will be obtained the dependences between slippage and drawbar pull on various field conditions in this paper. When the tractor works by changing the drawbar pull, the distribution of vertical load on the front and rear axles changes, and it is difficult to set. This problem will be discussed in this article, too.

Keywords: drawbar pull, inflation pressure, slippage, vertical weight.

Introduction

Agricultural machinery has a negative impact on the soil surface due to the high vertical loads of the wheels and slippage. Deep tracks are formed in light and wet soil. Increased vertical load of the wheels results in increased impact to the soil surface. The result of these processes: soil compaction, soil structure destroying. For these reasons, the yields decrease and energy costs for tillage increase. The inflation pressure in the tires could be decreased to increase the tire-soil surface contact area to reduce slippage, which impacts the soil surface negatively. Increasing the wheel vertical load, the soil is compressed deeper. When the tire-soil surface contact area is larger, the specific pressure to the soil is lower and the soil compression is lower, too. Increased tire-soil surface contact area reduces specific soil pressure.

Slippage is one of the main indicators that measures the tire tractive performance and tire-soil surface interaction of the tractor [1-5]. This is one of the main energy-economic and ecological indicators. Slippage depends on the drawbar pull. It is found that increasing slippage the drawbar pull increases. The maximum drawbar pull can be developed on 15-20 % slippage [4]. But of the negative impact to the soil surface maximum slippage of a wheeled tractor can be no more than 15 % [4]. The recommended value of slippage must be taken into account form tractor aggregates. For example: during plowing works the recommended value of slippage should be about 8-12 % [4] If slippage is too high or too low, energy losses increase [4; 5].

Researchers at the Waterways Experiment Station studied the problem of tractive ability of tires under different soil conditions (sandy soil and clay soil). The research studies indicate that about 20-55 % of the energy developed to the drive tractor wheels is wasted in the tire-soil interaction [6].

Another of the most important indicators of the tractor is working utility. It is power utilization to useful work. Working in a variety conditions of soil at as much as possible higher drawbar power often needs to change the ballast weight to reduce slippage of the driving wheels [4; 5; 7-13]. Ballasting a tractor (changing its mass) is changing its weight distribution of the front and rear wheels. Therefore, tractor ballasting is necessary, so that the ballast weights counterbalance by hanging or mounted implements from the rear wheels to the front and to decrease the machine overturning moment. During agricultural works, the rated vertical load of the rear wheel compacts 60 % of the total weight of the tractor [14]. F. Zoz [14] recommends to calculate the transferred weight of the drawbar pull from the front wheels to rear wheels by simplified formula:

$$\Delta G = \xi \cdot F_t \quad (1)$$

where ΔG – transferred weight;
ξ – coefficient of the weight transfer;
F_t – drawbar pull.

F. Zoz found [14] that working with mounted implements with power – positional controller $\xi = 0.65$; semi-mounted implements $\xi = 0.45$ and trailing implements $\xi = 0.2$.

Scientists recommend decreasing the inflation pressure in the tires to reduce slippage [11-13]. The manufacturers are developing tires with low inflation pressure as possible. In addition, there are more popular inflation pressure changing systems in agriculture nowadays. Choosing the inflation pressure the recommended slippage values, vertical loads of the driving wheel and working speed in agricultural works should be taken into account.

Analyzing slippage of the driving wheel possibilities it is needed to know its dependencies on the inflation pressure in the tires, tire vertical load, drawbar pull developed on different soil types. The soil physical and mechanical properties are variable, so slippage dependencies need to be estimated experimentally.

Materials and methods

For investigations dry (soil hardness in 5 cm depth was 0,85 MPa, soil moisture in 5 cm depth was 8 % in the soil preparing for sowing; soil hardness in 5 cm depth was 0,90 MPa, soil moisture in 5 cm depth was 11 % in the stubble) stubble and ready for sowing soil was selected. For slippage dependence of the drawbar pull tests at different inflation pressures in the tires a tractor New Holland T5070 was used. The investigations were performed with turn off front driving wheels and blocked rear differential. The tractor drawbar pull was performed by pulling a tractor “Zetor 10540”, which was connected by a rigid link. There was a drawbar pull measurement sensor fitted.

The drawbar pull of the tractor was directed horizontally. The height of the hitch mechanism was 0.83 meters from the ground surface. The protector depth of the rear tires of the tractor “New Holland T5070” is 40 mm.

The main technical data of the tractors used in the experiments are shown in Table 1.

Table 1

Technical data of tractors

Technical data	“New Holland T5070”	Zetor 10540
Rated engine power, kW	83	78.3
Rated engine speed, rpm	2300	2250
Weight of the tractor, kg	4250	4336
Wheelbase, mm	2350	2380
Front tires	Michelin Multibib 340/65R24	Barum 16.9 – 14 R38
Rear tires	Michelin Multibib 540/65R34	Barum 12.4 – 28 TZ19
Weight of the front axle, kg	1990	1848
Weight of the rear axle, kg	2260	2488

The distance, which the rear wheels of the tractor drove in 10 revolutions during the experiments, was measured. Laser rangefinder Bosch PLR 50 was used to measure the distance. Measurement accuracy is 2 mm.

The coefficient of slippage of the tractor rear wheels was calculated by equitation:

$$\delta = \frac{s_{th} - s_a}{s_{th}} = \frac{s_{4\times2(F_t)} - s_{4\times2(F_t=0)}}{s_{4\times2(F_t)}} \tag{2}$$

where s_{th} – the theoretical distance of the rear wheel travel during 10 revolutions;
s_a – the actual distance of the rear wheel travel during 10 revolutions;
$s_{4\times2(Ft)}$ – distance, which drives the rear wheels in 10 rates when the tractor has loaded drawbar pull.
$s_{4\times2(Ft=0)}$ – distance, which drives the rear wheels in 10 rates when the tractor was without drawbar pull.

The theoretical distance s_{th} was determined according to the American Society of Agricultural Engineers (ASAE) standard S296.2 as the distance travelled per revolution of the wheel when operating at the specified zero condition;

All investigations were performed on the soil preparing for sowing and stubble driving on the third diapason and second gear, on 1400 rpm engine speed with blocked rear differential.

The inflation pressures in the rear tires of the tractor were changed during the investigations. Pressures were selected for the investigations respectively 2.4; 2.0; 1.6; 1.2; 0.8 bar.

Vertical load of the wheels was determined on a flat area on an electronic axle weigher WPD-2. Tractor "New Holland T5070" was loaded on different drawbar pull. The measurement error 2 kg.

In the safeguard on reliability all tests were repeated three times.

Results and discussion

The results of "Tractor New Holland T5070" vertical load on the rear wheel of the drawbar pull are shown in Figure 1. The vertical load increases in proportion to the load biggest drawbar pull. Vertical load increases in proportion to the load major drawbar pull by regression equitation from Figure 1.

$$G_v = 0{,}06004 \cdot F_t + 22.304 \quad (3)$$

where F_t – drawbar pull;
G_v – vertical load of the rear driving wheel.

When the tractor was loaded 2.9 kN of the drawbar pull, the vertical rear wheel load was 24.0 kN, and at 13.22 kN of drawbar pull it was 30.14 kN respectively (Fig. 1).

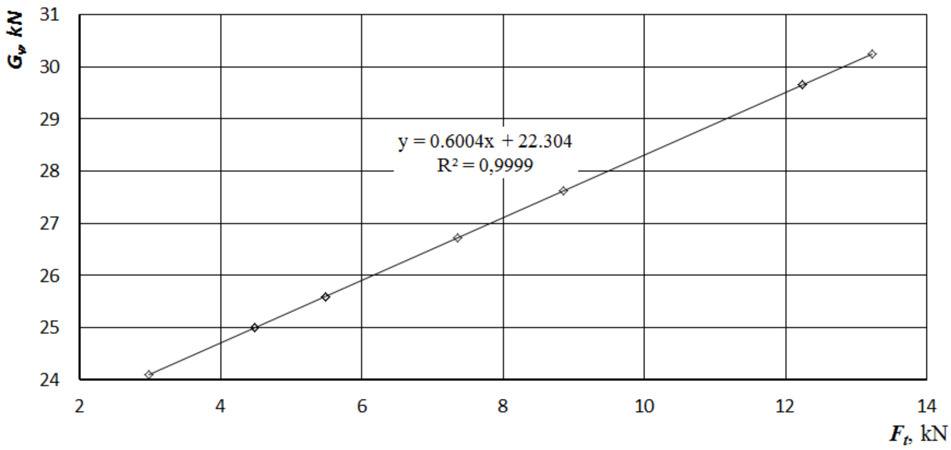

Fig. 1. **Tractor "New Holland T5070" vertical load of the rear wheels G_v dependence on drawbar pull of F_t**

Slippage also depends on the weight distribution (weight transfer effect) of the driving wheels of the tractor, there is shown the vertical load on the rear driving wheel dependence of drawbar pull in the same graph (Fig. 1 and 2).

The dependence of slippage on the tractor "New Holland T5070" of the rear driving wheels in the soil preparing for sowing loaded on different drawbar pull is shown in Figure 2.

Figure 2 shows that driving a tractor "New Holland T5070" and loaded at a low 3.0 kN drawbar pull, the coefficient of slippage is about 0.03 ... 0.04. When the tractor is loaded of 8 kN drawbar pull, the coefficient of slippage is 0.12 at the inflation pressure in the rear tires of 2.4 bar of the tractor and 0.08 when the pressure in the rear tires is 0.8 bar. When the tractor is loaded of 10 kN drawbar pull, the coefficient of slippage is 0.17 and 0.12 at the inflation pressure in the rear tires of 2.4 and 0.08 bar respectively. And when the tractor is loaded 12 kN of drawbar pull, the slippage coefficient increases to 0.25 and 0.2 when the inflation pressure is 2.4 and 0.8 bar respectively. At 8 kN drawbar pull the coefficient of slippage decreases in 8 % to reduce the inflation pressure in the rear tires of the tractor from 2.4 bar to 0.8 bar respectively. At 12 kN drawbar pull the coefficient of slippage decreases in 14 % to reduce the inflation pressure in the rear tires of the tractor from 2.4 bar to 0.8 bar respectively.

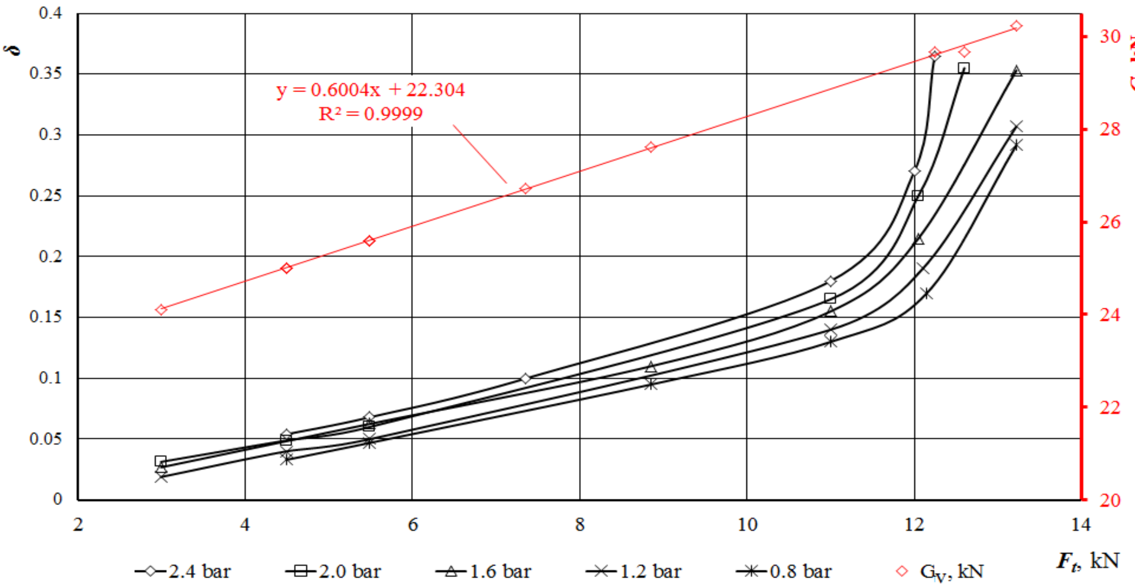

Fig. 2. **Dependence of the rear wheel coefficient of slippage δ on different inflation pressure in the rear tires of drawbar pull F_t driving the tractor "New Holland T5070" in the soil preparing for sowing, when the inflation pressure in the rear tires: 0.8; 1.2; 1.6; 2.0, 2.4 bar. Vertical load of the rear wheels G_v dependence on drawbar pull F_t**

The dependence of slippage on the tractor "New Holland T5070" of the rear driving wheels in the stubble loaded on different drawbar pull is shown in Figure 3.

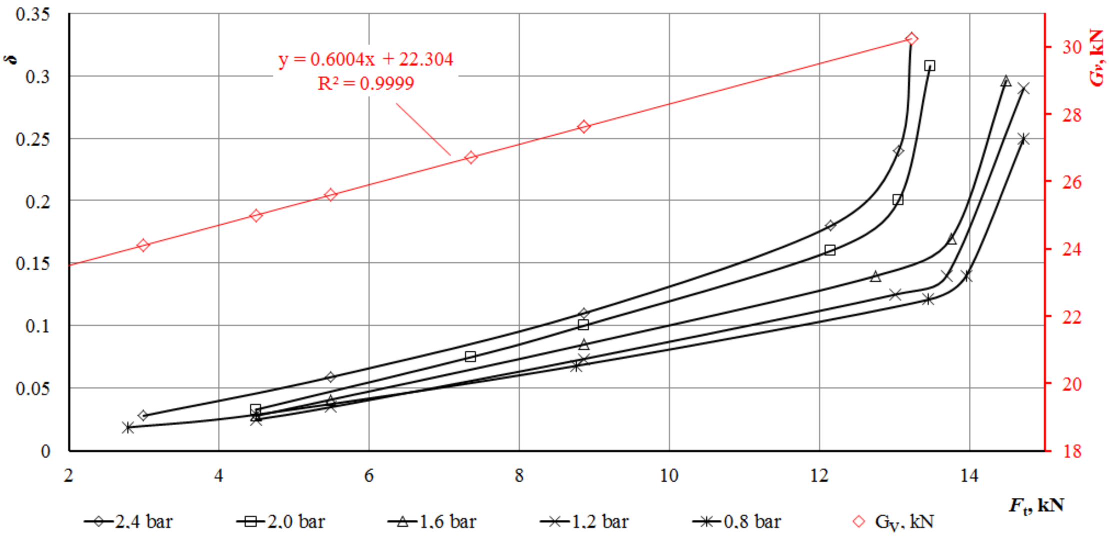

Fig. 3. **Dependence of the rear wheel coefficient of slippage δ on different inflation pressure in the rear tires of drawbar pull F_t driving the tractor "New Holland T5070" in the stubble, when the inflation pressure in the rear tires: 0.8; 1.2; 1.6; 2.0, 2.4 bar; vertical load of the rear wheels G_v dependence of drawbar pull F_t**

Figure 3 shows that driving a tractor "New Holland T5070" and loaded at a low 3.0 kN drawbar pull, the coefficient of slippage is about 0.02 ... 0.03. When the tractor is loaded of 8 kN drawbar pull, the coefficient of slippage is 0.12 at the inflation pressure in the rear tires of 2.4 bar of the tractor and 0.05 when the pressure in the rear tires is 0.8 bar. When the tractor is loaded of 10 kN drawbar pull, the coefficient of slippage is 0.08 and 0.13 at the inflation pressure in the rear tires of 2.4 and 0.08 bar respectively. And when the tractor is loaded 12 kN of drawbar pull, the slippage coefficient increases to 0.20 and 0.14 when the inflation pressure is 2.4 and 0.8 bar respectively. At 8 kN drawbar pull the coefficient of slippage decreases in 10 % to reduce the inflation pressure in the rear tires of the tractor from 2.4 bar to 0.8 bar respectively. At 12 kN drawbar pull the coefficient of slippage decreases in 16 % to reduce the inflation pressure in the rear tires of the tractor from 2.4 bar to 0.8 bar respectively.

In both cases the slippage can be significantly reduced by reducing the inflation pressure in the rear tires from 2.4 bar to 0.8 bar, driving with tractor 4x2 wheel drive. The biggest effect is in the higher drawbar pull, when the tractor is loaded 10 ... 12 kN drawbar pull, then the slippage decreases by 14…16 % driving the tractor "New Holland T5070" in soil and stubble.

Conclusions

1. Increasing the drawbar pull from 2.9 to 13.22 kN, the vertical rear load increases of 26 %.
2. Driving the tractor New Holland T5070 loaded 7…8 kN drawbar pull in the soil preparing for sowing, the coefficient of slippage decreases 8 % to reduce the inflation pressure in the rear tires of the tractor from 2.4 bar to 0.8 bar. At 10…12 kN drawbar pull the coefficient of slippage decreases up to 14 to reduce the inflation pressure in the rear tires from 2.4 bar to 0.8 bar.
3. Driving the tractor New Holland T5070 loaded 7…8 kN drawbar pull in the soil preparing for sowing the coefficient of slippage decreases 10 % to reduce the inflation pressure in the rear tires of the tractor from 2.4 bar to 0.8 bar. At 10…12 kN drawbar pull the coefficient of slippage decreases up to 16 to reduce the inflation pressure in the rear tires from 2.4 bar to 0.8 bar.

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