PERFORMANCE OF 4 WD TRACTOR ON GRAVELED ROAD

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Abstract. The distribution of the vertical loads of the axles and the air pressure in the front and rear tires have an influence on the kinematic discrepancy between the front and rear driving wheels during the exploitation of the 4 WD tractor. The kinematic discrepancy between the front and rear driving axle has an influence on fuel efficiency on the 4 WD driven tractors, too. The performance of 4 WD driven tractors during transport work on the graveled road is analyzed in this paper. The interaction of the different air pressure of the front and rear driving wheels with the road surface is analyzed in this paper. There are shown the results of the experimental investigation of the kinematic discrepancy influence on fuel efficiency during exploitation of the 4 WD driven tractor on the graveled road in this paper.

Keywords: 4 WD tractor, tractive force, inflation pressure, ballast, slippage, kinematic discrepancy, fuel consumption.

Introduction

The driving wheels of the tractor always slip, when the tractor is loaded by the maximum tractive force. There are two ways to evaluate slippage: to increase the resistance of the traction and to increase the vertical load of the driving wheels. This action would simultaneously allow increasing the grip with the road surface of the driving wheels [1; 2]. There are these groups of methods used to decrease slippage of the tractor nowadays:

- ballasting;
- using wider (dueling) wheels;
- using front driving wheels;
- changing the inflation pressure of the tire.

It is known that the maximal tractive force of the tractor depends on the vertical load of the driving wheels and the tractive force is increasing by ballasting of the tractor. But the fuel efficiency is increasing too, because the mass of the tractor is increased of the tractor, too [3]. When the soil is moist and soft the wheels sink in to the soil deeply by increased vertical load of the wheels. The soil or road surface is not steady during the exploitation of the tractor [4]. It takes too much time to dueling wheels of the tractor, the overall dimension and mobility is increased by dueling or widening wheels.

The tractive efficiency is increasing by turning on the front driving wheels of the tractor. But the tractive efficiency depends on the front axle lead ratio. It was found, that the highest tractive efficiency is when the lead ratio of the front driving wheels is not higher than 5 % [5] and depends on the interaction between the tire road contact area. For example, the highest tractive efficiency on sandy soil is when the lead ratio of the front driving wheels is 4 % and on clay soil it is 2 % [6].

Low tire inflation pressure tires are very popular nowadays. The exploitation period of the tire, economical effect, and tractive force of the tractor depend on the air pressure in the tires. The air pressure in the tires must be increased on hard roads. The air pressure in the tires must be about 1.4-1.6 bar on the road in higher speed, for example, during transport work [6].

It was found that correct air pressure in the tires reduces the power loses in association with the tire and road surface contact area. In this case the controlled air pressure in the tires is increasing the friction between the tire road surface. As a result of it – increased driving force of the wheel of the vehicle [1; 2]. The contact area of the front and rear wheels can be increased or decreased 20 % by changing the air pressure in the tires [7]. It is known that lower inflation pressure is used in soft or moist soils. Although increased contact area between the tire road surface does not let tires to sink into the soil. The waste of driving efficiency is decreased and the soil compressed less. But on hard roads deformation of the tire increases the wastes of driving efficiency [3; 7-9].

The driving radius of the wheel and theoretical speed of the axis change by changing the air pressure in the tire. Although, the factual speed of the driving axles is equal to the tractor speed, because the driving axles of the tractor are connected with the tractor steadily [5; 10-12].

Tractors with all driving wheels are made that the weight of the tractor is dissipated 60 % and 40 % for the rear and front axle [3; 4]. Holding for these proportions is very important, because gear ratios for the driving wheels are dissipated that the theoretical speeds of driving axles would be the same [9]. However, to hold these proportions in exploitation is rather difficult. The mass of implements of the tractor and the angle of the tractive force have influence on the weight of the axles. Non proportional loads are deforming the driving wheels differently than it is provided and in this case the dynamic radius of the driving wheels changes not proportionally [10-15].

Materials and methods

Tests were performed on the tractor "Zetor 10540". The main technical dada of the tractor "Zetor 10540" are shown in Table 1.

Table 1

Technical data of tractor "Zetor 10540"

Property	Value
Weight of the tractor, kg	4336
Wheelbase, mm	2380
Front tires	16.9 – 14 R38
Rear tires	12.4 – 28 TZ19
Weight of the front axle, kg	1848
Weight of the rear axle, kg	2488

The tractive force of the tractor was directed horizontally. The tractive force (9 kN) of the tractor "Zetor 10540" was performed by the hitched tractor "Belarus MTZ 82". The tractive force was chosen so that the load of the tractor compounds 80 percent of the maximal power of the tractor, when the tractor pulls 14-15 tons mass of the trailer.

The main technical dada of tractor "Belarus MTZ 82" are shown in Table 2.

Table 2

Technical data of tractor "Belarus MTZ 82"

Property	Value
Wheelbase, mm	2450
Weight of the tractor, kg	3820
Front tires	8.30-20
Rear tires	15.5-38

The weight of the driving wheels of the tractor was measured with electronic portable axle scales WPD-2, error 1 kg.

The tests were performed on the graveled horizontal road. All tests were performed in turned on and turned off front driving wheels, driving in the same section of the road and in the same direction. In the safeguard on reliability the tests were repeated three times.

The distance was measured, which drove the front and rear wheels of the tractor in 10 rates. Digital laser rangefinder Bosch PLR 50 was used for measuring the distances on 2mm error.

The slippage (or skid – when the result was obtained with a minus sign) of 4WD tractor front and rear wheels when the tractor traveled with loaded tractive force was calculated by equation:

$$\delta = \frac{s_{th} - s_a}{s_{th}} 100 = \frac{s_{4\times4(F_t=9kN)} - s_{4\times2(F_t=0)}}{s_{4\times4(F_t=9kN)}} 100, \% \qquad (1)$$

where s_{th} is the theoretical distance of the front or rear wheel travel during 10 revolutions accordingly;

s_a is the actual distance of the front or rear wheel travel during 10 revolutions in 4WD condition.

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; $s_{4\times4(Ft=9\ kN)}$ – the distance, which drives the front and rear wheels with turned on front driving wheels in 10 rates when the tractor was loaded tractive force.

Percent of slippage (or skid – when the result was obtained with a minus sign) of 4WD tractor front and rear wheels when the tractor traveled without tractive force was calculated by equation:

$$\delta = \frac{s_{4\times4(F_t=0)} - s_{4\times2(F_t=0)}}{s_{4\times4(F_t=0)}} 100, \% \tag{2}$$

where $s_{4\times4(Ft=0)}$ and $s_{4\times2(Ft=0)}$ – the distance, which drives the front and rear wheels with turned on and turned off front driving wheels in 10 revolutions, when the tractor traveled without tractive load.

The kinematic discrepancy was calculated by equation:

$$k_n = \frac{1-\delta_f}{1-\delta_r} \tag{3}$$

where δ_f and δ_r – the slippage of the front and rear driving wheels.

The tests were performed on different inflation pressure on the front and rear driving wheels: 0.8; 1.6; 2.4 bar.

The fuel consumptions B_h were measured by fuel – oil flow meter HENGST AIC 4004 on 1 ml error.

Results and discussion

There is shown the dependence of the slippage (slid) of the front and rear driving wheels of the tractor on different inflation pressure values in the front and rear tires in Figure 1. The inflation pressure in the front tires is: 0.8; 1.6; 2.4 bar. And in the rear tires the inflation pressure is 2.4 bars.

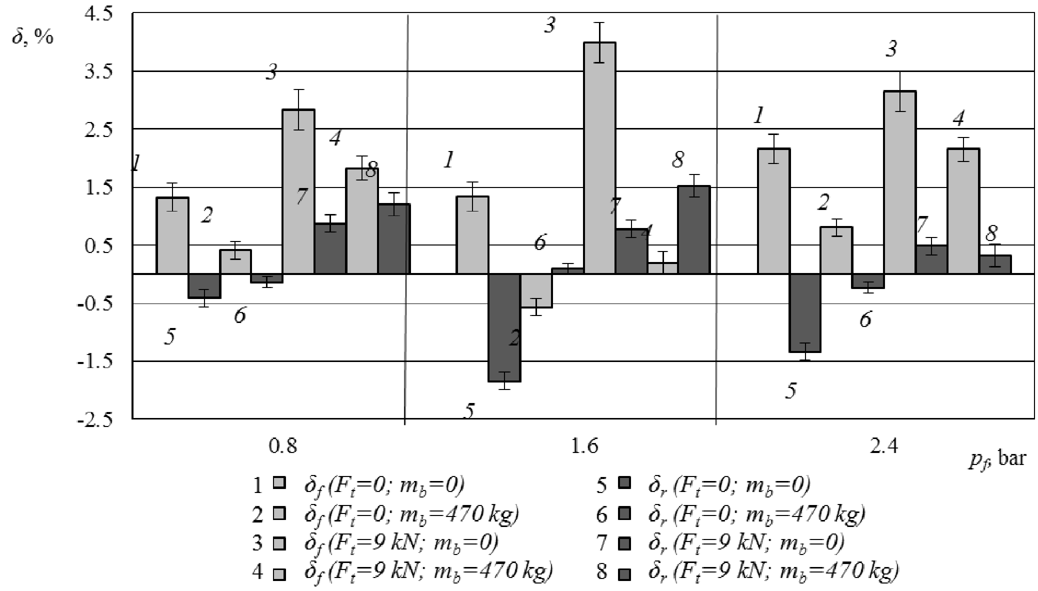

Fig. 1. **Dependence of slippage of the front δ_f and rear δ_r wheels of the tractor on different air pressure in the front tires p_f driving without ballast (m_b = 0), with ballast (m_b = 470 kg), without tractive force (F_t = 0), loaded with tractive force (F_t = 9 kN); Inflation pressure in the front tires p_f: 0.8; 1.6; 2.4 bar**

Figure 1 shows, that traveling with the tractor without tractive force and ballast on the front hydraulic lift, the minimal slippage and slid of the rear and front driving wheels is 1.32 % and 0.41 % respectively when the inflation pressure in the front tires is 0.8 bars. The minimal slid and slippage of the rear and front driving wheels is 0.57 % and 0.09 % respectively, when the tractor travels with ballast on the front hydraulic lift and the inflation pressure in the front tires is 1.6 bars.

Minimal slippage of the front and rear driving wheels is 2.83 % and 0.87 %, when the tractor travels loaded with tractive force without ballast on the front loader, the inflation pressure in the front tires is 0.8 bars. When the tractor is loaded with tractive force and ballast on the front hydraulic lift the minimal slippage of the front and rear driving wheels is 0.19 % and 1.52 % when the air pressure in the front driving wheels is 1.6 bar.

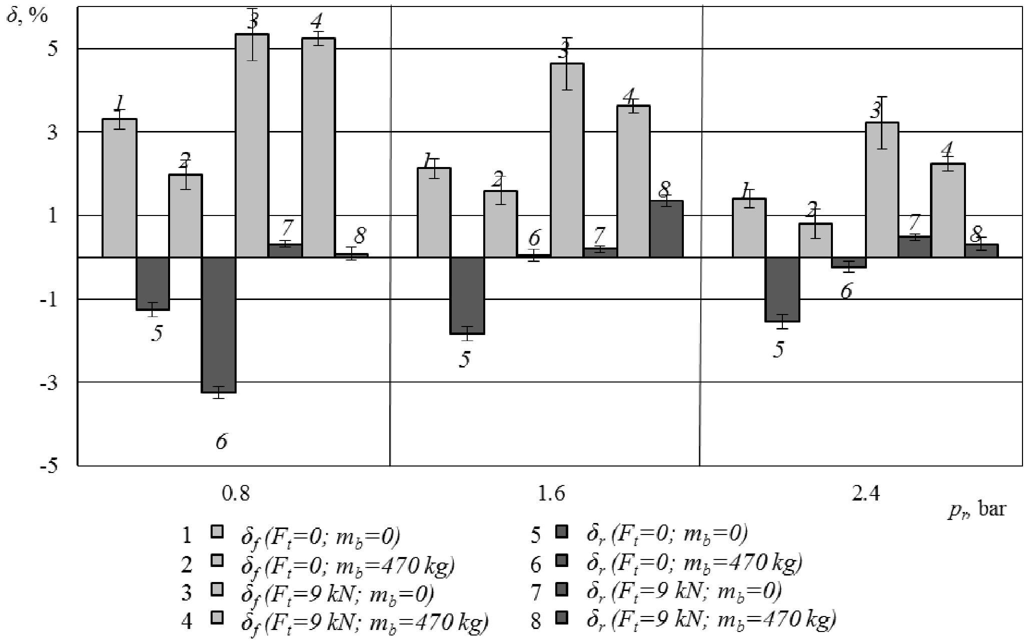

Fig. 2. **Dependence of slippage of the front δ_f and rear δ_r wheels of the tractor on different inflation pressure in the rear tires p_r driving without ballast (m_b = 0), with ballast (m_b = 470 kg), without tractive force (F_t = 0), loaded with tractive force (F_t = 9 kN); inflation pressure in the rear tires p_r: 0.8; 1.6; 2.4 bar**

Slippage (slid) of the front and rear driving wheels of the tractor on different inflation pressure values in the rear tires is shown in Figure 2. The inflation pressure in the rear tires is: 0.8; 1.6; 2.4 bar. In the front tires the inflation pressure is 2.4 bars.

Figure 2 shows, that traveling with the tractor without tractive force and ballast on the front hydraulic lift, the minimal slippage and slid of the rear and front driving wheels is 2.12 % and 1.34 % respectively when the inflation pressure in the rear tires is maximal 2.4 bars. The minimal slippage and slid of the rear and front driving wheels is 0.80 % and 0.32 % respectively, when the tractor travels with ballast on the front hydraulic lift and the inflation pressure in the front tires is 2.4 bars

Minimal slippage of the front and rear driving wheels is 0.87 % and 2.83 %, when the tractor travels loaded with tractive force without ballast on the front loader, the inflation pressure in the front tires is 0.8 bars. When the tractor is loaded with tractive force and ballast on the front hydraulic lift the minimal slippage of the front and rear driving wheels is 1.19 % and 0.83 % respectively, when the inflation pressure in the front tires is 0.8 bars.

In Figure 3 the dependence of the kinematic discrepancy between the front and rear driving wheels of the tractor when the inflation pressure in the rear tires was: 0.8; 1.6; 2.4 bars is shown.

Fig. 3 shows that kinematic discrepancy of the driving wheels of the tractor was equal to 1, when the air pressure in the front tires was 1.6 bar as in the rear tires there was maximal 2.4 bars with ballast on the front hydraulic lift.

The fuel efficiency of the tractor on the different inflation pressure values in the tires is shown in Figure 4. The inflation pressure in the rear and front tires is: 0.8; 1.6; 2.4 bar.

The minimal fuel consumption is 3.14 $l \cdot h^{-1}$ when the tractor traveled without tractive force and ballast on the front hydraulic lift. When the tractor traveled with ballast on the front hydraulic lift the fuel consumption increases by 4 % as the air pressure in the front tires was 1.6 bars and in the rear tires 2.4 bars respectively.

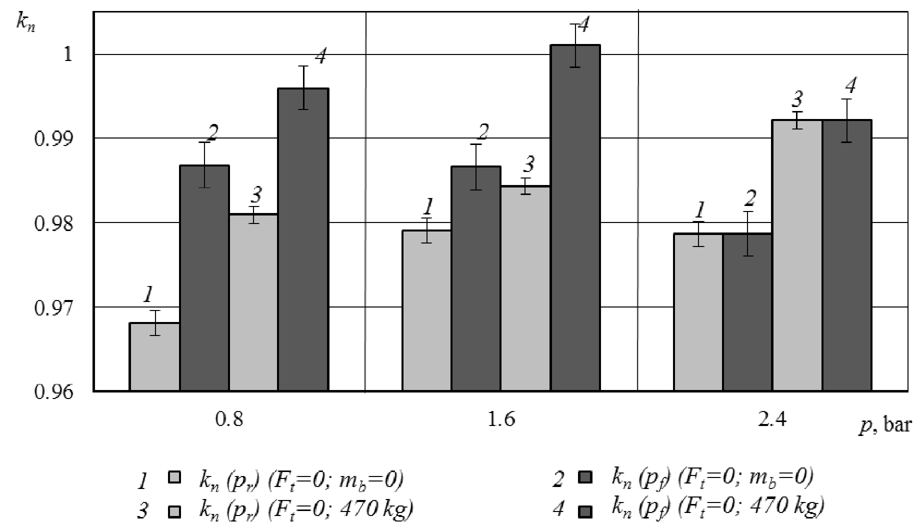

Fig. 3. **Kinematic discrepancy k_n of the driving wheels of the tractor driving without ballast (m_b = 0), with ballast (m_b = 470 kg) on different inflation pressure on the front (p_f) and rear (p_r) driving wheels: 0.8; 1.6; 2.4 bar**

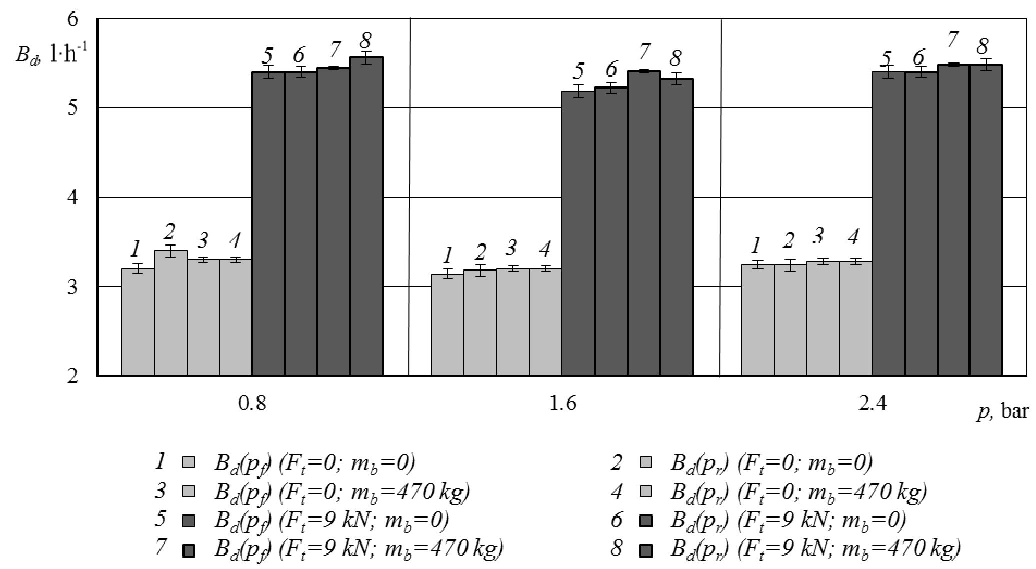

Fig. 4. **Dependence on fuel consumption on different inflation pressure in the front (p_f) and rear (p_r) tires driving without ballast (m_b = 0), with ballast (m_b = 470 kg), without tractive force (F_t = 0), loaded with tractive force (F_t = 9 kN); the inflation pressure in the tires p: 0.8; 1.6; 2.4 bar**

When the tractor was loaded with tractive force without ballast on the front hydraulic lift, the minimal fuel consumption is 5.18 l·h^{-1} and it increased by 4.3 % when the tractor traveled with ballast on the front hydraulic lift. The air pressure in the in the front tires was 1.6 bars and in the rear tires 2.4 bars respectively.

The results could be applied to the tractor Zetor 10540 with trailer during transport work on graveled roads. The total weight of the trailer with cargo would be 14-15 tons. The load of the tractor amounts to 80 percent of the maximal load of the tractor.

Conclusions

1. The minimal slippage of the front driving wheels and slid of the rear driving wheels, when the tractor travels without tractive load and ballasted 470 kg on the front hydraulic lift is when the inflation pressure in the front and rear tires is 2.4 and 0.8 bar respectively.

2. The minimal slippage of the front and rear driving wheels is, when the tractor is loaded with tractive force without ballast when the inflation pressure in the front and rear tires is 2.4 bar.
3. There is no kinematic discrepancy between the driving wheels when the inflation pressure in the front driving wheels is 1.6 bar as in the rear driving wheels 2.4 bar during the exploitation with 470 kg ballast on the front hydraulic lift.
4. The minimal fuel consumption of the tractor with 4X4 driving wheels is 5.18 and 3.14 $l \cdot h^{-1}$, when the tractor works without ballast with loaded and unloaded tractive force when the air pressure in the front driving wheels is 1.6 bar, in the rear driving wheels 2.4 bar respectively.

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