

THE THEORETICAL ESTIMATION OF THE TRACTOR DRIVE WHEELS SLIPPAGE WITH THE VARIABLE TIRE INFLATION PRESSURE.

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Abstract: The main tractor parameters that defy suitability of tractors to perform traction work is traction power and driven axle wheel-slide. Different mass tractors wheel-slide on the same soil differs and depends on the vertical load (G), which falls on the driven axle wheels. When choosing tractors and agriculture implements it is needed to foresee the formed implements traction and economical parameters. To achieve this goal mathematical modeling methods are used. The purpose of mathematical modeling is to determine traction characteristics of the tractor, taking into account various factors. At this moment there are tractor traction models created, that describe various agriculture and field tasks. Most Mathematical models mainly assess the hardness of the soil and driven wheel geometrical parameters. However, one of the most important parameters in assessing the suitability of a tractor unit is the tractors driven wheels slide. To decrease wheel-slide and to increase the driving wheels grip with soil there are different methods being used: Ballast weights, use of twin wheels and changeable air pressure in the tires. However current mathematical models do not consider the change of air pressure in tires. A mathematical module was created, which takes into calculations the driven wheels wheel-slide having different air pressure in the tires.

Keywords: TRACTOR IMPLEMENT, MATHEMATICAL MODELING, TRACTION POWER, WHEEL-SLIDE, AIR PRESSURE

1. Introduction

Tractors wheels slippage is the most important tractors and it's implements forming energetic – economic and ecologic parameter. (Osinenko et al.,2015) It is one of the main parameters that shows the tires and the roads (soils) surface interaction. (Lee et al. 2016; Molari et al. 2012; Grečenko, and Prikner 2014). Different mass tractors wheel slippage on the same soil differs and depends on the vertical load (G), which falls on the driven axle wheels (Damanauskas and Janulevičius 2015, Zoz 1972) In agrotechnical requirements allowed slippage limits are set. When ploughing stubble ground wheel slippage is recommended to be around 8...12%. Wheeled tractor permissible wheel slippage – up to 15 %. When there is wheel slippage, a higher traction power can be achieved. Although when it is too high or too low energy loss rises. (Batitiato and Diserens 2013, Lacour et al. 2014). A tractor can achieve the highest traction power when there is 15...20% wheels slippage. Although due to the negative effect to the soil, the maximum allowed wheel slippage for wheeled tractors must not exceed 15%. (Lee et al. 2016; Molari et al. 2012).

At this moment, one of the most popular ways to decrease wheel slippage is changeable air pressure in the driven tractor tires. It is advisable to decrease air pressure in the driven tires, then the tire deforms, the area of its support increases, and the grip with surface improves. In addition, high wheel slippage reduced tractors coefficient of efficiency (performance) and cost-effectiveness.

The aim of this work was to find a mathematical formula for theoretical calculation (prognosis) of tractors driven wheel slippage, while evaluating air pressure in the tires.

2. Results and Discussion

When compiling vehicles and aggregates and preparing them for work, advance calculations (forecasting) of wheel slippage is an important task to determine energetic and economic parameters.

The tractor pulling forces expositive a non-dimension form: the net traction coefficient of the tractor (c_T), the gross traction or torque coefficient (c_G), and the total motion resistance coefficient of the tractor (c_W) offer to evaluate tractors wheel slippage using the formula:

$$s_t = s_{lim} \left[1 - \left(1 - \frac{F_T}{F_T^{lim}} \right)^b \right] \quad (1)$$

where: s_t – theoretical wheel slippage, F_T^{lim} – maximum traction power at the limit wheel slippage, kN ; F_T – tractors traction power, kN; s_{lim} – limit wheel slippage (wheeled tractors, $\delta_{rib}=40\%$). b –grade indicator.

Since in almost all cases the mathematical model's error is close to 20% and, in some cases, exceeds, also this mathematical model does not evaluate the air pressure in the tires.

From the analysis of the tractors experimental studies wheels slippage dependency from traction power on various tires air pressures, it was decided, that instead of using constant grade indicator (b) to use the indicator as a changing value, which reflects the air pressure in the tractors tires.

We can call this size air pressure in the tires coefficient (k_p). Then we can rewrite the formula(ar naudoti expression) as follows:

$$s_t = s_{lim} \left[1 - \left(1 - \frac{F_T}{F_T^{lim}} \right)^{k_p} \right] \quad (2)$$

The main goal of this mathematical module is to calculate tractors wheel slippage, according to maximum nominal traction power F_T^{lim} . Nominal traction power is determined experimentally when wheel slippage is at 40%.

Experimental tests were performed to determine the coefficient (k_p) depending on the air pressure in the tires. Tractors driven wheel slippage was determined by experimental tests according to standard methodology and calculated according to the formula (Gray et al.,2015; Janulevičius et al.,2017):

$$S = \frac{v_t - v}{v_t} \tag{3}$$

here v_t – theoretical speed; v – actual speed.

Experiments were done using tractors "CASE IH Farmall U Pro 115", "New Holland T5070". Tractor "CASE IH Farmall U Pro 115" and "New Holland T5070" main technical characteristics are given in table nr.1. During the tests, the air pressure was changed at the front and rear tires of the "CASE IH Farmall U Pro 115" and "New Holland T5070". The air pressure in front and rear tires was the same. The tests were done with maintaining the air pressure at 80, 120, 140, 160, 200, 240 kPa. The tests have been conducted with the front axle on and off and the rear differential lock permanently disabled. The load on the tested tractors was generated by pulling tractors "Zetor 10540" and "MTZ 82". Two tractors were used to fully load the tested tractor "CASE IH Farmall U Pro 115" or "New Holland T5070", which were connected with a rigid towing bar, which was horizontal to the surface of the road. The test execution scheme is shown in figure 1.

Table 1: "CASE IH Farmall U Pro 115" and "New Holland T5070" technical data:

Technical data	CASE IH Farmall U Pro 115	New Holland T5070
Engine power, kW	84	83
Weight of the tractor, kg	4336	4350
Wheelbase, mm	2380	2350
Front tires	Trelleborg 480/65 R24	Michelin Multibib 40/65R24
Rear tire	Trelleborg 540/65 R38	Michelin Multibib 540/65R24
Weight of the front axle, kg	2004	1990
Weight of the rear axle, kg	2896	2260

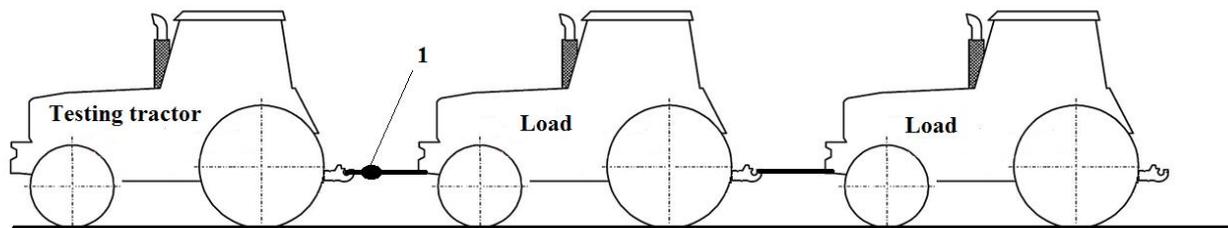


Fig 1. Test execution scheme. 1- force measuring.

Coefficient (k_p) dependence on the air pressure of the tractor "Case Farmall 115 U" (tires "Michelin Multibib 540/65R34") and tractor "New Holland T5070" (tires "Trelleborg 540/65 R38") tires using 4X4 driven wheels is given in figure 2.

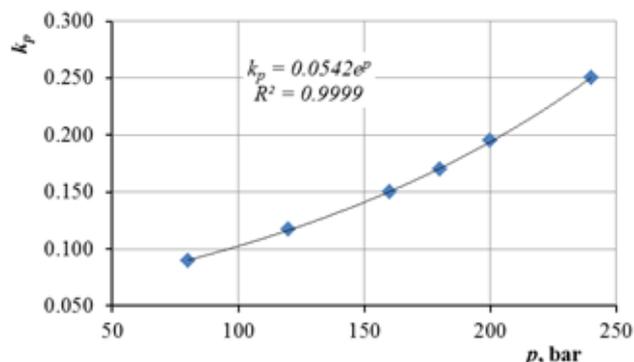


Fig 2. Coefficient (k_p) dependency from air pressure in the tractors tires.

Coefficient (k_p) was determined using tractors with 4X2 driven wheels. The difference between the two tractors results didn't reach 5%. In figures 2 and 3 tractors "New Holland T5070" test results are displayed.

As we can see from figure 2 air pressure coefficient (k_p) directly depends from air pressure in tractor tires according to exponential dependence:

$$k_p = 0,0542e^p \tag{4}$$

here: p – air pressure in tractors driven wheel tires kPa using tractors 4X2 driven wheels.

With a pressure of 80 kPa in tractor tires, the coefficient (k_p) for air pressure in tires is 0,090. When the nominal air pressure in the tractor tires is 180 kPa, the coefficient of air pressure in the tires is considered to be nominal and equals 0,170. (Fig. 2).

After assigning corresponding values of coefficient (k_p) to the formula (3) and after calculations, we obtain wheel slippage theoretical dependency from traction power. A comparison of these dependencies with experimental curves is presented in Figure (3).

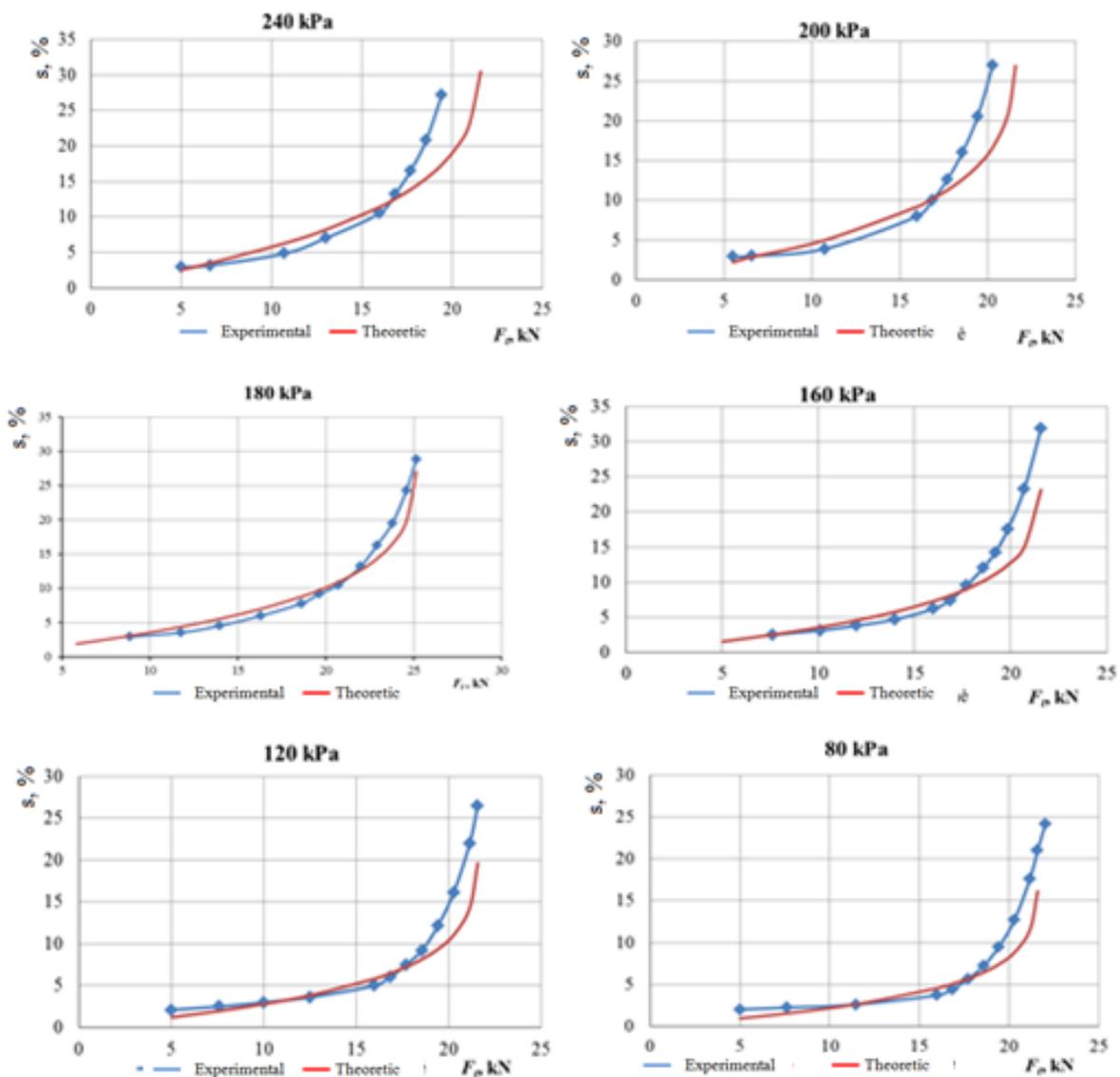


Fig 3 Tractors "New Holland T5070" wheel slippage and traction power theoretical and experimental dependencies using tractors 4X2 driven wheels

Conclusions

1. Having done literature analysis, it has been found that, known tractors wheels slippage determining mathematical modules, cannot directly take into consideration the air pressure in tires.
2. To calculate traction and wheel slippage, of the mathematical equation, coefficients (k_p) dependency from air pressure in tractors tires was found(set).
3. A mathematical model was made for the tractors "New Holland T5070" wheel slippage prediction from traction power, which is appropriate having small or medium loads, up to 17-18 kN traction power.

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