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THEORETICAL RESEARCH TO IMPROVE TRACTION PERFORMANCE OF WHEELED TRACTORS BY USING A SUPLEMENTARY DRIVEN AXLE

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Abstract: *Nowadays tractor manufacturers tend to reduce the specific weight of those. For that purpose, this work aims to improve traction performances of universal wheeled tractors by using a supplementary driven axle actuated by power timed plugs of tractor.*
Keywords: *driven axle, tractor, traction performances*

1. INTRODUCTION

Lately, on a global level within the tractors industry it is observed a more and more accentuated tendency to reduce the constructive weight of tractors. This tendency has been generated on one side, by the necessity of cutting the tractor's price and on the other side, by the necessity of improving the traction and economic indexes of the tractor when it is exploited under different circumstances.
The traction and economic qualities of the tractor (tractive efficiency, productivity, fuel consumption etc.) depend on a large scale on the correlation of two parameters: tractor's weight at exploitation and the nominal power of the engine [1].
For the consumed power used for the tractor's motion to be minimal, the weight of tractor needs to be the smallest possible. On the other side, this weight needs to suffice in order to ensure a good adherence of the system of rolling up the soil. As tractors are exploited in a large range of velocities, they should have a variable exploitation weight: small for the transportation works with high velocities – when the drawbar load is reduced and great in the case of exploitation with low velocities – when the drawbar load is great. But most of the times it is difficult to modify the exploitation weight of the tractor, its traction qualities for the inferior velocity stages are not limited to the power of the engine. This way, for low working velocities the tractor's engine is not used rationally [2].
An effective solution for improving the utilization degree of the engine and, at the same time, for improving the traction and economic efficiency of the tractor regarding varied agricultural works, is using a supplementary driven axle.
In order to underline the efficiency of these systems, as follows, there is drawn up a comparative study of the traction qualities of the tractor 4x4, with and without supplementary driven axle.
The basic scheme of the system formed by the tractor combined with the supplementary driven axle mechanically activated by means of the tractor PTO (power take off) is presented in Figure 1.

2. TRACING THE TRACTION CHARACTERISTIC OF THE TRACTOR IN BOTH CASES

For tracing the theoretical traction characteristics only 5 stages from the gearbox - with values within 4.30 and 12.53 km/h – as this interval of velocities is the most used when effecting most of the agricultural works.

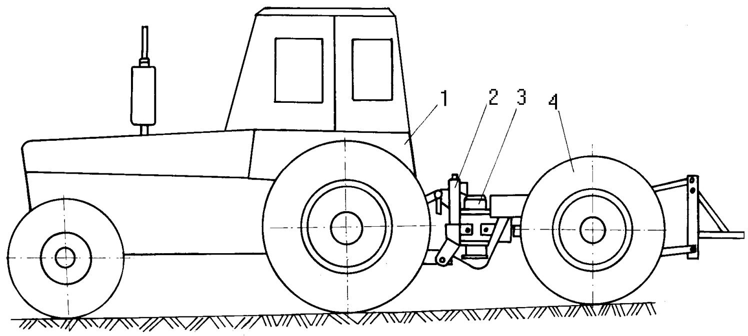


Figure 1: The tractor with driven axle: 1 – tractor; 2 - support; 3 –vertical articulation; 4 – active tractor axle.

2.1. Mathematic model of the interaction between the roll up system and the soil

The **tractor slipping** δ is calculated as function of the specific driving force, which is defined by equation:

$\varphi_m = F_m / G$ for 4x4 tractors.

$$\delta = \frac{A\varphi_m - B\varphi_m{}^2}{C - \varphi_m}, \tag{1}$$

where: A, B, C are coefficients depending on the driving wheels tire dimensions, and especially on the road conditions.

The efficiency of the tractor can be estimated by means of the traction efficiency η_t, defined by the equation:

$$\eta_t = \eta_{tr}(1-\delta)\left(1-\frac{R_r}{F_m}\right) = \eta_{tr}(1-\delta)\left(1-\frac{fG}{F_t + fG}\right), \tag{2}$$

where: η_{tr} is the total efficiency of tractor transmission; R_r - the rolling resistance force of the tractor, $R_r = fG$; f - the rolling resistance coefficient of the tractor on ground; G - the tractor weight in the center of gravity; F_m - the traction tangential force (driving force), developed by the engine; F_t - the drawbar load.

$$F_m = F_t + R_r. \tag{3}$$

By means of the relation we may trace the curve representing the traction efficiency depending on the traction force Ft representing, in fact, the potential traction characteristic of the tractor.

The real moving speed value of the tractor can be determined by the relation:

$$V = V_t(1-\delta), \tag{4}$$

where V_t is the theoretical traveling speed of the tractor, in m/s;

The driving force and a drawbar load. In case the tractor rolls up on a horizontal area, in a stabilized system (V = const.), the traction balance of the tractor has the following form:

$$F_m = F_t + R_r = \frac{M_e i_{tr} \eta_{tr}}{r}, \tag{5}$$

where i_{tr} is the transmission total reduction ratio;. R - the dynamic radius of the driving wheels, m; M_e - the effective torque of the engine, Nm.

The traction power P_t, in kW, is defined by the equation:

$$P_t = 10^{-3} F_t V, \tag{6}$$

2.2. Mathematical model of the engine's characteristic

In most of the papers the power curve is approximated to a third degree parabola:

$$P_e = P_n\left[\alpha_1 \frac{n}{n_n} + \alpha_2\left(\frac{n}{n_n}\right)^2 + \alpha_3\left(\frac{n}{n_n}\right)^3\right], \tag{7}$$

and the curve of the torsion moment in the shaft is approximated, as a consequence, to a second degree parabola:

$$M_e = M_n\left[\alpha_1 + \alpha_2\frac{n}{n_n} + \alpha_3\left(\frac{n}{n_n}\right)^2\right], \tag{8}$$

where α_1, α_2 and α_3 are determiners, for the above mentioned functions to approximate in the best possible way the external characteristic obtained experimentally. The values of these coefficients depend on the relations n_m / n_m and M_m / M_n

On the branch controlled by the regulator of the engine rotation characteristic, the dependency $M_e=f(n)$ is considered, generally, linear and, as a result:

$$M_e = M_n\frac{n_0 - n}{n_0 - n_n}, \tag{9}$$

where: n_0 is the maximum no-load speed of the engine (the maximum speed of the crankshaft), $n_0 = (1{,}06\ldots1{,}1)n_n$; n_n - the nominal rpm.

For diesel engines used for tractors, the specific fuel consumption curve is described more precisely by the function:

$$c = c_n\left[1{,}55 - 1{,}55\frac{n}{n_n} + \left(\frac{n}{n_n}\right)^2\right]. \tag{10}$$

The **nominal specific fuel consumption** can be determine, approximately, by the relation $c_n = 1{,}05 \cdot c_{\min}$, in g/(kW.h).

The hourly fuel consumption, in kg/h, can be calculated by the relation:

$$C = 10^{-3}cP_e.$$

On the linear branch of the engine characteristic, the hourly fuel consumption has the following equation:

$$C = C_g + \frac{C_n - C_g}{P_n}P_e, \tag{11}$$

where: C_g is the hourly fuel consumption at n_o ; C_n - the hourly fuel consumption at n_n

In Figures 2...4 a comparative analysis of the traction and economic efficiency of tractor is presented, in the standard variant and in case a driven axle is used.

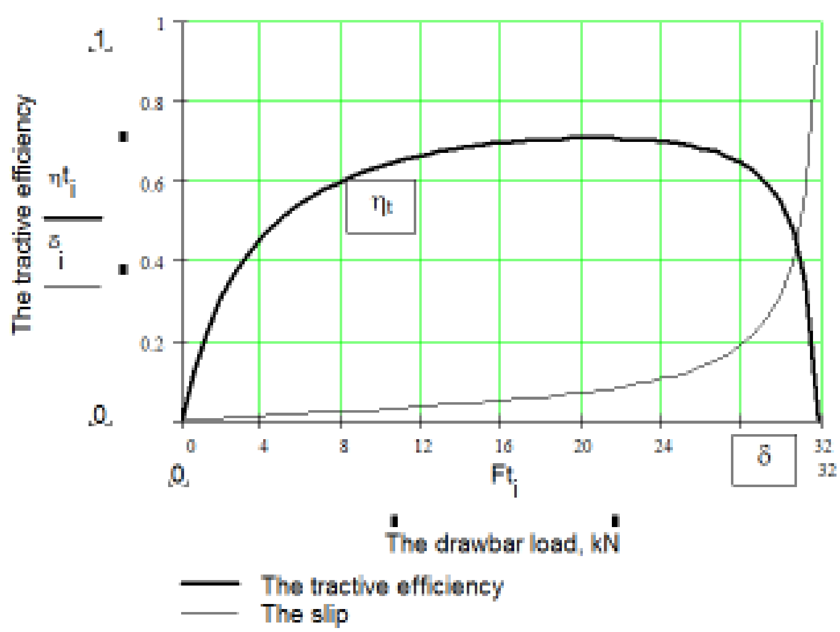
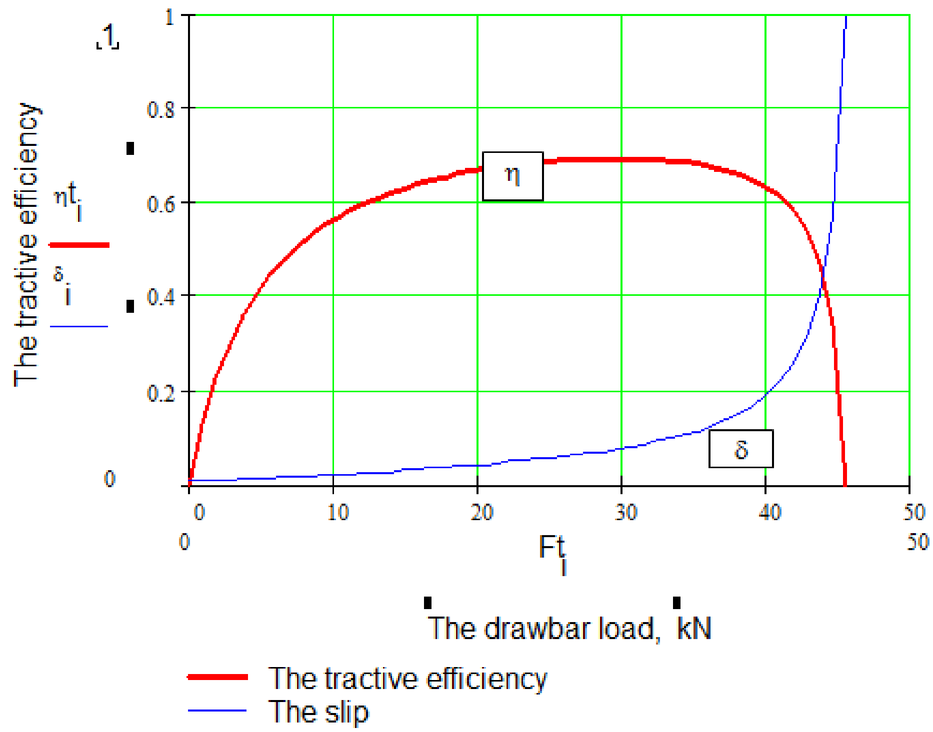


Figure 2: Variation of skidding and a traction efficiency with drawbar load:
a. – standard tractor;



b. – tractor + driven axle.

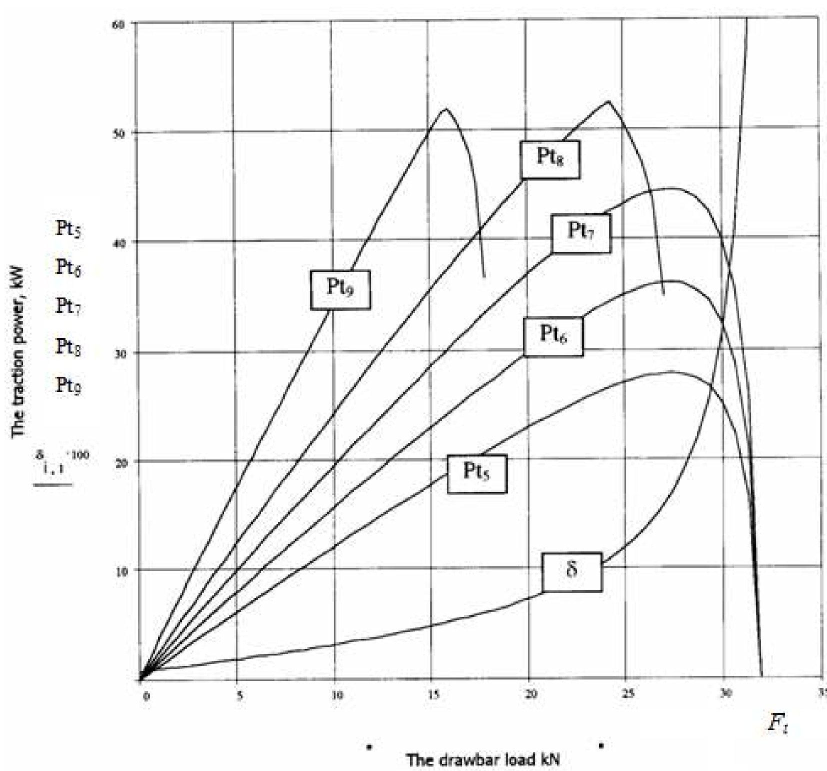
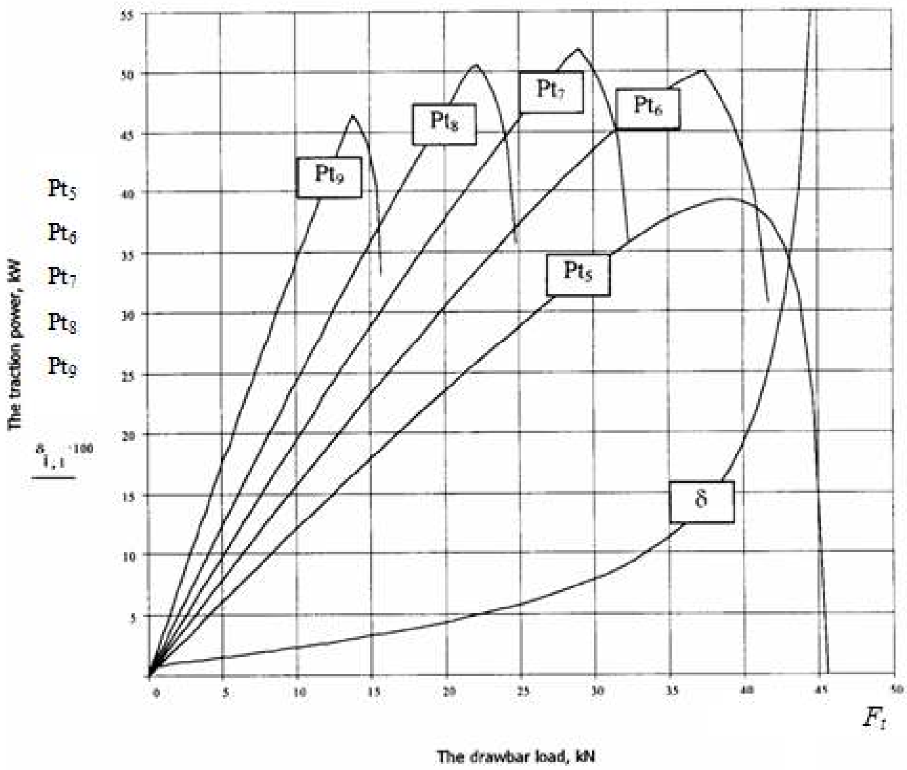


Figure 3: Variation of the traction power with drawbar load:
a. – standard tractor;



b. – tractor + driven axle.

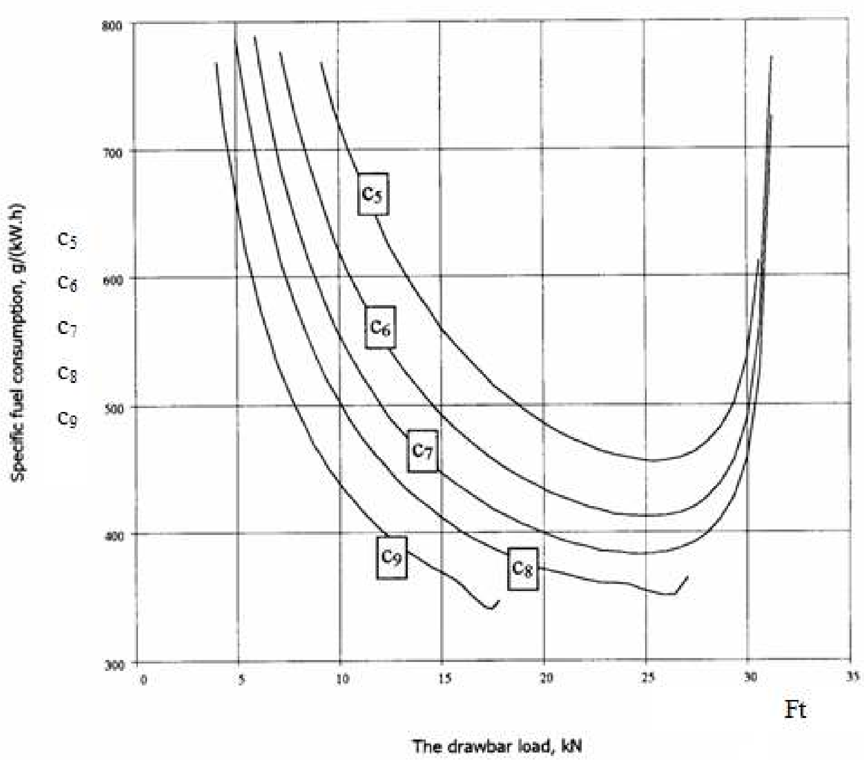
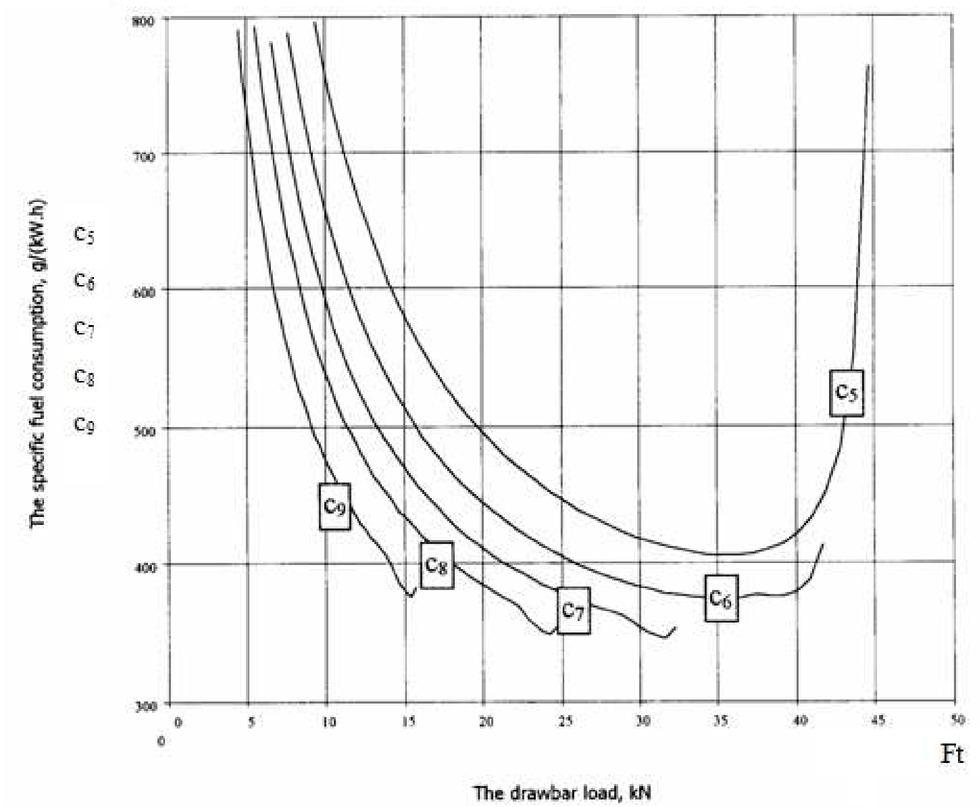


Figure 4: Variation of the specific fuel consumption with draw bar load:
a. – standard tractor;



b. – tractor + driven axle.

3. CONCLUSIONS

- The limits of the traction forces in which the tractor has a high efficiency are increased. Thus, the traction efficiency of the standard tractor is above 0.6 in the interval 8kN….29.3kN (Figure 2, a), and the traction efficiency of the tractor with a supplementary driven axle is above 0.6 in the interval 12.1….41.9 kN (Figure 2, b).
- The traction force limited by the adherence increases 1.43 times more at the tractor equipped with supplementary driven axle, than at the standard tractor (Figure 2).
- Within the limits of the adopted velocities, at the tractor equipped with supplementary driven axle, the number of the stages of velocity to which the engine is used totally, increases from 2 to 4 (Figure 3).
- At the tractor equipped with supplementary driven axle the respective minimal fuel consumption is smaller and is moved to the area of the great traction forces (Figure 4).

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