THE IMPACT OF U-650 AND VALTRA T-190 ROLLING SYSTEM ON SOIL

IMPACTUL SISTEMULUI DE RULARE ASUPRA SOLULUI PENTRU TRACTOARELE U-650 ŞI VALTRA T-190

ŢENU I., COJOCARIU P., CÂRLESCU P., ROŞCA R., CAZACU D., VLAHIDIS V.
University of Agricultural Sciences and Veterinary Medicine Iasi, Romania

Abstract. *The paper establishes, based on the concepts and researches regarding the subject, the impact of agricultural tractors rolling system on soil compaction. Using these concepts, the tire-soil contact patch and the specific pressure are determined at the tire-ground interface level for the U-650 and the Valtra T-190 tractors. The present research aims to evaluate the influences of the tire type, tire pressure, soil type and agricultural soil characteristics.*
Key words: tractor tire, patch area, pressure on soil.

Rezumat. *În cadrul lucrării se determină, pe baza conceptelor dezvoltate în acest sens, impactul sistemului de rulare, din componenţa unor tractoare, asupra solului. Pe baza acestor concepte se determină mărimea petei de contact şi presiunea specifică, care se dezvoltă la nivelul zonei de interferenţă dintre sol şi anvelopele cu care sunt echipate tractoarele U-650 şi Valtra T-190. Cercetările efectuate au în vedere determinarea influenţei tipului de anvelopă, presiunii din anvelopă, categoriei de sol şi stării solului.*
Cuvinte cheie: roţi de tractor, suprafaţă de contact, presiunea pe sol.

INTRODUCTION

One of the most important characteristics of tractors is the pressure on the soil for each tire, which must not exceed 100 kPa. In order to evaluate the average tire pressure on the ground it is necessary to know the force (weight) acting on the tire-soil interface and the contact surface with the ground.

MATERIAL AND METHOD

Different mathematical models were used in this paper, established by different authors (researchers) in order to determine the tire contact patch area with the ground, for front and rear wheels of tractor U-650 and Valtra T-190 (table 1). The mathematical models presented by different authors to calculate the wheel - ground contact surface, are empirical, semi-empirical and theoretical. Theoretical models use different equations to calculate the geometric surface of the tire-soil contact patch, for example the known equations for determining the area of the circle, ellipse, square or rectangle. For empirical equation models, researchers use different empirical constants, obtained from a large number of experiments. Then, for each variant of the contact patch area equation, the average pressure exerted by the wheel with tire to the ground was evaluated, dividing the corresponding wheel weight (force) to the contact area.

Table1

Equations used to calculate the contact surface of wheel with soil

Equation no	Equation determined by:	Significance of formulas:
1	Komandi [6] $A = \frac{c \cdot W^{0,7} \cdot \sqrt{\frac{b}{d}}}{p_i^{0,45}}$, (m^2)	A - tire contact patch area with the ground , m^2 ; W - weight (force) of the wheel on the ground, kN; b - tire wheel width, m; d - exterior tire diameter, m; p_i - tire air pressure chamber, kPa; c - constant, depending on soil texture (0.30 ... 0.44, 0.31 was used); δ- the amount by which the radius decreases wheel tire, due to its weight (force), (m) ; r - unloaded wheel radius, which is down on the ground with a force equal to zero (m) ; r_1 - loaded wheel radius, being ground down by its own weight (force) (m) ; c_1 - a constant, depending on tire and soil characteristics (0.175 ... 0.270, 0.270 was used) ; h - the tire height section, m; G - indicate the pressure of the wheel ·on the floor, kPa; $h = 0,77 \cdot b^{0,89}$, $\delta = r - r_1$; b_c - width of the wheel contact patch with the ground, m; Lc - length of the wheel contact patch with soil, m ; z - wheel sinking into the ground or wheel traces depth, m ; r_b - transverse radius of the tire,m ; b_w - lugged tire tread width, m; k - empirical constant, depending on the characteristics of the tire (18 ... 33, used 33), k - empirical constant depending on the characteristics of the tire (0.40
2	Silversides and Sundberg [10] $A = \frac{0,90 \cdot W}{p_i}$, (m^2)	
3	Grecenko [4] $A = \pi \cdot \delta \cdot \sqrt{d \cdot b}$, (m^2), in which $\delta = r - r_1$	
4	Grecenko [4]: $A = c_1 \cdot d \cdot b$, (m^2)	
5	Krik [7] $A = 8 \cdot \delta \cdot h$, (m^2), in which $h = 0,77 \cdot b^{0,89}$, (m) established by Lyasko [8]	
6	Krik [7]: $A = 5,3 \cdot h^2 \cdot \delta \cdot \left(\frac{p_i}{W} \cdot d \cdot b\right)^{0,8}$, (m^2)	
7	Pillai and Fielding [9]; $A = 1,85 \cdot \delta^{\frac{2}{3}} \cdot b \cdot r^{\frac{1}{3}}$, (m^2)	
8	Godbole [3] $A = \pi \cdot \delta \cdot \sqrt{d \cdot h}$, (m^2), in which h = b, and $\delta = h \cdot 0,67 \cdot \left(\frac{p_i \cdot d \cdot b}{W}\right)^{-0,8}$, (m)	
9	Dwyer [1] $A = \frac{W}{G}$, (m^2), in which $G = \frac{W}{b \cdot d} \cdot \sqrt{\frac{h}{\delta}} \cdot \left(1 + \frac{b}{2 \cdot d}\right)$, (kPa),and $h=0,77.b^{0,89}$	
10	Ziani and Biarez [12] $A = \frac{\pi}{4} \cdot b_c \cdot l_c$, (m^2), in which $b_c = 2 \cdot \sqrt{z \cdot (2 \cdot r_b - z)}$, (m) $l_c = 2 \cdot \sqrt{z \cdot (2 \cdot r - z)}$,(m);z = 0,147r, and $r_b = \frac{b}{2}$	

11	Febo [2] $A = \frac{\pi}{4} \cdot b_c \cdot l_c$, ($m^2$), in which $b_c = b_w \cdot (1 - \exp^{-k \cdot \delta})$ (m); $l_c = 2 \cdot \sqrt{d} \cdot \delta^j$ (m); $\delta = r - r_1$, (m)	... 0.44, 0.41 was used).
12	Sohne [11] $A = 2 \cdot b \cdot \sqrt{d \cdot z}$, ($m^2$)	

RESULTS AND DISCUSSIONS

In order to calculate the wheel-soil contact surface and the average pressure exerted by it on the ground, the U-650 and Valtra T-190 tractors front and rear wheels features were used, as presented in table 2.

Table 2

Front and rear wheels features of tractor U-650 and Valtra T-190

Wheels features	U-650 Tractor		Tractor ValtraT-190	
	front wheel	***rear wheel***	***front wheel***	***rear wheel***
Exterior tire diameter , d (m)	0,850	1,600	1,400	1,800
Tire wheel width, b (m)	0,1651	0,3556	0,4293	0,5283
Unloaded wheel radius, r (m)	0,425	0,800	0,700	0,900
Loaded wheel radius, r_1 (m)	0,385	0,720	0,665	0,875
Lugged tire tread width, b_w (m)	0,145	0,320	0,410	0,500
Wheel weight, G (kN)	6,227	11,500	17,210	17,063
Tire air pressure chamber, p_i (kPa)	216	89	160	160

In each of the four categories of tire wheel (front wheel and rear wheel of Valtra T190 and U-650 tractors) the wheel-ground contact area and the average pressure exerted on the ground was calculated, for all 12 variants of the surface equation. The results are presented in tables 3 and 4.

The U-650 tractor front wheel

The wheel - ground contact surface varied depending upon the version of equation used for calculating from 0,0181 m^2 (variant 6) to 0,0761 m^2 (variant 12). For the variant 12, the contact surface is with 320.4% bigger than the variant 6 value (it is 4,2 times higher). It is estimated that the difference between the two extreme options (6 and 12) is too great.

The average pressure exerted by the wheel on the soil varied, depending on the version of the equation used to calculate the wheel contact area with the ground, between 81,835 kPa (variant 12) to 344,745 kPa (variant 6). For variant 6, the average ground pressure is with 321.3% bigger than the one in variant 12 (it is 4,21 times higher).

Table 3

Wheel contact surface with soil (m^2)

Equation number	U-650 Tractor		Valtra T-190 Tractor	
	front wheel	***rear wheel***	***front wheel***	***rear wheel***
1	0,0438	0,107	0,128	0,124
2	0,0259	0,116	0,096	0,096
3	0,0471	0,189	0,085	0,076
4	0,0379	0,153	0,162	0,256
5	0,0496	0,196	0,101	0,087
6	0,0181	0,13	0,096	0,145
7	0,0269	0,113	0,075	0,08
8	0,0367	0,172	0,176	0,188
9	0,065	0,261	0,161	0,198
10	0,0558	0,219	0,21	0,337
11	0,0411	0,209	0,132	0,13
12	0,0761	0,308	0,325	0,515
average	**0,043**	**0,181**	**0,145**	**0,186**

The average value of the 12 variants is 165,929 kPa. We believe that the difference between the two extreme options (12 and 6) is high. Regarding media variants, it exceeds with 65,929 kPa the 100 kPa maximum permissible pressure value of agro requirements.

Table 4

The wheel average pressure exerted on the ground [kPa]

Equation number	U-650 Tractor		Valtra T-190 Tractor	
	front wheel	***rear wheel***	***front wheel***	***rear wheel***
1	142,318	107,313	134,248	136,868
2	240	98,888	177,777	177,777
3	132,344	60,692	201,994	222,899
4	164,342	74,86	106,054	66,456
5	125,557	58,569	169,424	195,51
6	344,745	88,027	177,974	117,478
7	231,278	101,245	227,552	210,965
8	169,752	66,712	97,353	90,629
9	95,825	43,98	106,324	85,966
10	111,656	52,431	81,86	50,542
11	151,507	54,887	130,41	130,869
12	81,835	37,277	52,81	33,092
average	**165,929**	**70,406**	**138,648**	**126,587**

The U-650 tractor rear wheel

The contact surface of the wheel with the ground varied from 0.1070 m^2 (variant 1) to 0.3080 m^2 (variant 12). In version 12, the contact surface is with 188% bigger than the one of variant 1 (it is 2.88 times higher). It can be said that the difference between the two extreme options (1 and 12) is quite large.

The wheel average pressure exerted on the ground has different values, ranging from 37,277 kPa (variant 12) to 107,313 kPa (variant 1). For variant 1, the average ground pressure is with 187,9% bigger than the pressure of variant 12 (is 2,879 times greater). The average of all 12 variants is 70,406 kPa. It appears that the difference between the two extreme options (12 and 1) is quite large. It should be pointed out that the average of the 12 variants is less than the maximum admissible of 100 kPa. Comparing the average values, leads to the conclusion that the rear wheels of the tractor U-650 average ground pressure is much lower than the front wheels value (70,406 kPa to 165,929 kPa).

Front wheel of Valtra T-190 tractor

Contact surface of the wheel with the ground ranged from 0,0750 m^2 (variant 7) to 0,3250 m^2 (variant 12). The contact surface for variant 12 is with 333.3% bigger than the variant 7 one (it is 4.33 times higher). The difference between those two extreme options (7 and12) is significant. The average pressure exerted by the wheel on the ground varied from 52,810 kPa (version 12) to 227,552 kPa (variant 7). For variant 7, the average ground pressure is with 330,9 % bigger than the pressure of variant 12 (is 4,309 times greater). The average of the 12 variants is 138,648 kPa. It is estimated that the difference between the two extreme options (12 and 7) is high. It should be noted that the average of 12 variants exceeds the maximum admissible (100 kPa) with 38,648 kPa. It is worth mentioning that the average ground pressure Valtra T-190 tractor front wheels, is lower than the one recorded for the U-650 tractor (the variants average is 138,648 kPa compared with 165,929 kPa).

Rear wheel of the Valtra T-190 tractor

Tire-soil contact patch ranged from 0,0760 m^2 (variant 3) to 0,515 m^2 (variant 12). In variant 12, the contact surface is with 577,6 % bigger than the one of variant 3 (it is 6,776 times higher). We believe that the difference between the two extreme options (3 and 12) is very high. The average pressure exerted by the wheel on soil had different values ranging from 33,092 kPa (variant 12) to 222,899 kPa (variant 3). For variant 3 the average ground pressure is with 573,6 % bigger than the pressure of variant 12 (is 6,736 times greater). The average value of the 12 variants is 126,587 kPa. It can be said that the average ground pressure difference between the two extreme options (3 and 12) is very high. Regarding the 12 variants average, it exceeds the maximum admissible (100 kPa) with 26 587 kPa Comparing the variants average, it is noted that the rear wheels of the Valtra T-190 tractor average ground pressure is lower than the front wheels (rear = 126,587 kPa and front =138,648 kPa). The comparison of the average values of the variants reveals that the rear wheels average ground pressure is much higher for Valtra T-190 tractor than for U-650 tractor (126,587 kPa, respectively 70,406 kPa).

CONCLUSIONS

It was found that, both the contact patch wheel - ground surface and the average pressure of the wheel on the ground, have remarkable differences between extreme variants: differences large enough for U-650 tractor rear wheels, great differences for front wheels of the two types of tractors and very large differences for rear wheels of the

Valtra T-190 tractor. This is the reason why for the interpretation of results it were taken into account the average values of the variants.

The best results in terms of average pressure of the wheel on the ground were obtained for the rear wheels of U-650 tractor, where the average of 12 variants (70,406 kPa) is less than the imposed limit of 100 kPa.

Regarding the rear wheels of the Valtra T-190 tractor, the average wheel ground pressure was 126,587 kPa, exceeding the imposed limit by agro-technical requirements.

For the front wheels of the Valtra T-190 tractor, average wheel ground pressure is 138.648 kPa (variants average value), exceeding the 100 kPa limit imposed even more.

For the front wheels of the tractor U-650 the average wheel ground pressure is higher, 165.929 kPa (mean variants). In this case, it exceeds the maximum limit imposed by 66 kPa.

Therefore the average pressure on the ground must be reduced, primarily for the front wheels of the U-650 tractor, but also for front and rear wheels of the tractor Valtra T-190, in order not to exceed the maximum limit of 100 kPa. One solution is to decrease the tractor's front wheels axle or rear wheel axle weights. Another solution, easier to apply, is to increase the diameter of the wheels. We believe that the most easily applied solution can be the increasing of tire wheel width.

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