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IJIEMR Transactions, online available on 26th Feb 2021. Link : https://ijiemr.org/downloads/Volume-10/Special

DOI: 10.48047/IJIEMR/V10/I03/56

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Volume 10, Issue 03, Pages: 239-246.

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CHARACTERISTICS OF THE PARAMETERS OF TRACTOR TIRES ON A NON-HORIZONTAL SUPPORT SURFACE

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Abstract. the article deals with the main questions about the service life of pneumatic tires of machine and tractor units that depend on operational and agrotechnical indicators, the reasons for reducing the resource and the scientific basis for increasing the resource.

Keywords. machine, tractor, unit, tires, operation, load, resource, wheel, pneumatic, pressure, design

I. Introduction.

Improving the technical level and ensuring the operational and agrotechnical indicators of machine-tractor units (MTA) are interrelated and are constantly in the focus of their design [1,2]. However, a number of questions to assess the impact of the wheel mover to the ground not horizontal surface is a major issue for japasene in foothill areas of the Republic of Uzbekistan. Thus, it is established that the determining parameter characterizing the level of operational and agrotechnical impact of MTA during operation is their maximum pressure on the soil during cotton processing. At the same time, there are still no recommendations on the calculation method for determining the internal air pressure in the tire, corresponding to the size of the tires and the pressure on the ground.

Purpose of the study -The aim of the study is to identify the regularities of the influence of the tire dimension and air pressure in the tire on the amount of pressure on the soil within the contact spot in accordance with operational and agrotechnical requirements for limiting the impact of running systems on the soil according to GOST 26955-86 "Agricultural mobile equipment. Norms of the impact of propellers on the soil"; theoretical justification and numerical experiment to establish the possibility of using the universal characteristics of tractor tires in assessing changes in the contact pressure of a pneumatic wheel propeller on the soil.

Materials and methods. The study uses the technical characteristics of the MTZ-80X cotton tractor, the provisions of GOST 7463-2003 " Pneumatic tires for tractors and agricultural machines. Technical requirements", GOST 26955-86 " Mobile agricultural machinery. Norms of the impact of movers on the soil", personal computer using Microsoft Excel 2010, Statistica10.

Results of the discussion. Based on the scheme of tire deformation during static tests (Fig. 1), to determine the maximum contact pressure, it is necessary to consider the tire characteristic in the form of a nomogram.

The reference properties of tractor tires are determined by the values of the area-the contact spot, the average-psr and the maximum pressure on this spot. When the tire is deformed under the action of normal (radial) load-Q, a contact spot with an area - G is formed, at which pressure is created on the base. The scheme of radial deformation, the shape of the contact spot and the plot of pressures on the base are shown in Figure 1.

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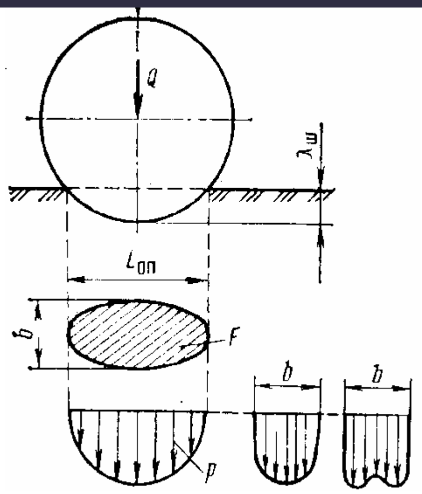

Fig. 1. Scheme of radial deformation and loading of the tractor wheel

Usually, the value of the area - G of the contact spot is determined by the greatest radial deformation of the tire-w, called the normal (radial) deformation of the tire. Several empirical formulas are used to approximate the values of the contact area of a smooth tire (uncoupled) and normal deformation of the tire [4]. The main ones have the form

$$\lambda_ш = \gamma_г cQ / (\pi P_c \sqrt{Db}); \quad (1)$$

$$F = \pi \lambda_ш \sqrt{Db} = Qc\gamma_г / p_c \quad (2)$$

where $\lambda_г$ - is a coefficient that takes into account the hardness of the base on which the tire rests. Usually $0,7 \leq \gamma_г \leq 1$; c - is a coefficient directly proportional to the width - - b of the contact spot, the pressure p_c of the air in the tires and inversely proportional to the load - Q; D - is the free diameter of the tire.

The value of the - F contact area depends mainly on the normal load on the wheel, the width of the tire, the air pressure in it and the hardness of the base. High soil hooks reduce the contact spot area on hard substrates. In this case, the pressure on the contact spot is distributed unevenly. Usually, tractor tires have no more than 30% of the total area of the contact spot

To characterize the bearing properties of the tire, a ratio of - Q / w is sometimes used, called the radial stiffness of the tire.

Formula (2), as indicated, gives only an approximate idea of the relationship between the reference properties and the tire load. For pneumatic wheels of agricultural machines, a more reliable formula was obtained by V. V. Smilsky [5] on the basis of processing experimental data by methods of similarity theory and dimensions:

$$Q = (p_c + p_э)\, z^{0,5}\, (Db_d/B_ш)\, \lambda_ш \sqrt[3]{\lambda_ш / H},$$

where p_c – is the air pressure in the tire, kPa; $p_э$ –is the pressure equivalent to the stiffness of the frame at different deformation of the tire, kPa (for tractor tires, when calculating, you can take $p_э \approx 110$ кПа); z – is the number of layers of cord in the tire; D, b_d, $B_ш$ H - respectively, the free diameter, disc width, width and height of the profile of the pneumatic tire, m; $\lambda_ш$ - is the radial deformation of the tire, m.

The load capacity of the tire is the maximum permissible value of the normal load-$Q_{до}$ at which, despite the radial deformation-- $\lambda_ш$, a given service life of the tire is provided at a given value of air pressure in it.

Thus, our analyses show rolling resistance proportional to the total rolling resistance losses (tractor speed, distance traveled $S \approx 1.5\, \alpha$ (α-contact area)), tire types, tire air pressure, values of deformation, lateral force, tread thickness, etc. of tractor tires.

The supporting properties of tractor tires of non-horizontal surfaces are very diverse. Indicators of deformation of pneumatic tires of the wheel of rowed cotton tractors or other agricultural machinery, must interact with the soil through the contact zone.

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As a result, complex deformations occur in pneumatic tires, which change its original shape and the size of individual elements. At the same time, the maximum deformations correspond to the sections of pneumatic tires located in the contact zone with the soil, and as they move away from the contact, the deformations proportionally decrease.

The load that the pneumatic tire perceives - is a normal load. When the pneumatic tire is compressed, a force contact zone is formed on the support surface with the soil, which balances the external load. The distance from the axis of the compressed pneumatic tire to the reference plane is called the static radius of the tire , and the difference between the free and static r_{CT}, radius is the normal deflection of the tire h_z [6].

The most widely formula R. Hackelia.

$$h_Z = G_K / \left(\pi P_{III} \sqrt{BD}\right)$$

It is advisable to use this formula in approximate calculations for air pressure not lower than *0.18 MPa (180 kPa)* for pneumatic tires. The dependence proposed by V. L. Biderman is more precise.

$$h_Z = \frac{C_2 G_K}{2P_{III}} + \sqrt{\left(\frac{C_2 G_K}{2P_{III}}\right)^2 + C_1 G_K}$$

where C_1 and C_2 -are constant coefficients for a given pneumatic tire, determined experimentally by a well-known method, and empirical dependences for determining the data in [7]. As a result of processing experimental data of static tests of rowed tractor pneumatic tires, the values of these coefficients are obtained, which are shown C_2 in Fig. 3.

The C_1 coefficients are almost independent of the tire model and determine it only by the number of layers of the frame (the more layers, the smaller it is).

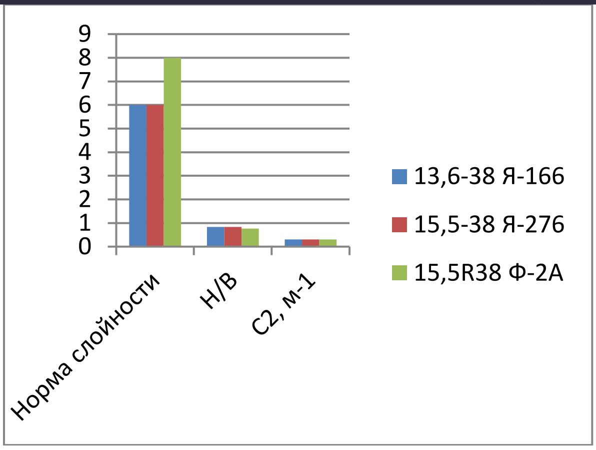

Figure 3. Constant coefficient C_2 value for tractor pneumatic tires

For six-layer tractor tires of diagonal construction, the coefficient C_1 = *(0.002-0.003)*10^{-5} m^2/N can be used. For pneumatic tires of model *R*, the coefficient C_1 is slightly higher and is $C_1 = (0.004\text{-}0.005)10^{-5}$ m^2/N. For eight-layer tilled tractor pneumatic tires C1 = (0.0012-0.0028)10^{-5} m^2/N.

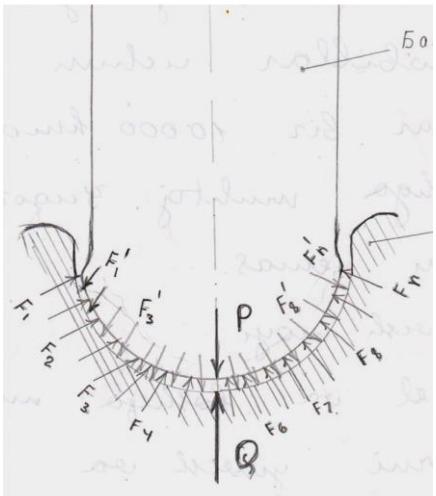

Figure. 3. Diagram of the deformation diagram of the leading tractor wheel tires

When assessing the normal deformations of pneumatic tires, for which no experimental determination of the load characteristic is given, the value of the coefficient can be determined by the well-known formula [8]:

$$C_2 = C_2' \sqrt{\frac{R_K' D'}{R_K D}}$$

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where C_2', R_K', D - is the known parameters of a tire that is close in design to the tire under study; R_K and D is the radius of curvature of the tire profile of a value approximately equal $2R_K$ the width of the profile of pneumatic tires. Based on the dependences of the normal deflection on the normal load, the corresponding stiffness coefficients are determined in the area of workloads, where the load characteristic is almost linear, and the stiffness shows that it does not depend much on the load.

The dependence of the normal stiffness coefficient on the air pressure for tilled tractor pneumatic tires is shown in Figure 5. The normal stiffness coefficient increases almost proportionally with increasing air pressure.

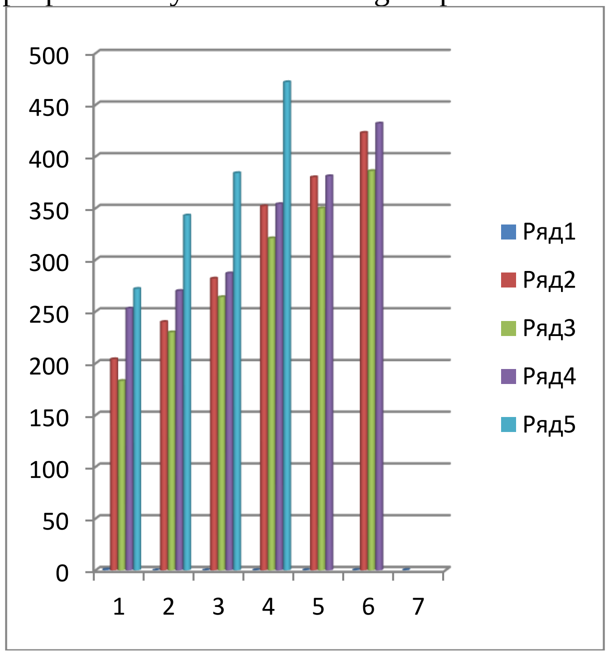

Figure.4. Dependence of the coefficient of normal stiffness on air pressure for rowed tractor tires: 1). 9,5-42 I-183; 2). 13,6/R38 I–318; 3) .15,5-38 I-166; 4). 18,4/15-30 R-319.

п/н	9,5–42 Я-183	13,6/R38 ЯР–318	15,5-38 Я-166	18,4/15-30 R-319
0,75	204	183	253	272
0,10	240	230	270	343
0,15	282	26	287	384
0,20	352	321	354	472
0,25	380	350	381	
0,30	423	386	432	

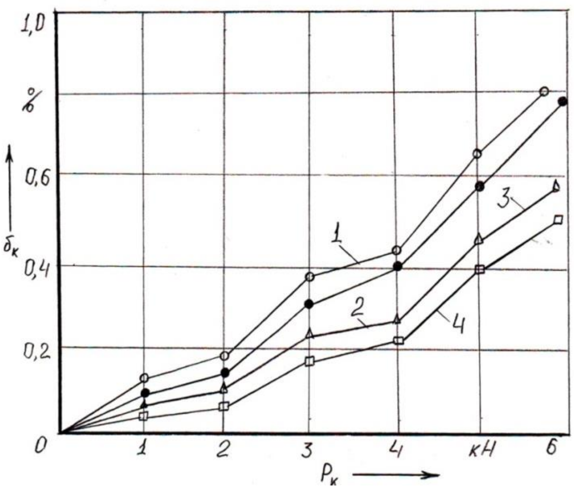

Figure 5. The dependence of the lateral movement of pneumatic tires 13.6/R38 YAR-318 on the lateral force at different normal loads (P =0.15 MPa): ***1).Gк =14 кН; 2).Gк=12 кН; 3).Gк=10 кН; 4).Gк=8 кН.*** Experimental values are shown in graphs 1,2,3,4; - - - • - - - values calculated by the formula: $h_y=8{,}73-55{,}7\,p-0{,}4G_кP+8{,}2P_y+0{,}16P_y^2$

The values h_Z and C_Z completely determine the statically compressed tire. All other static loads are applied to the compressed tire, Additionally loaded wheels with longitudinal P_X and lateral P_y forces, torsional, turning and tilting P_y moments M_K, cause additional deformations of the tire in the direction of action of these forces: tangential h_X, lateral h_y, torsional β, turning Θ and j tilting. If we consider the effect of each of these factors separately, the relationship between them and the corresponding deformations is the same (Fig.6).

Based on the primary dependencies of the loading of the compressed surface by forces and moments, the corresponding stiffness coefficients are calculated [5]:

$$C_y = \frac{\partial P_y}{\partial h_y}; \qquad C_\beta = \frac{\partial M_K}{\partial \beta};$$

$$C\sigma = \frac{\partial M_n}{\theta}$$

In the first approximation, the tangential elasticity of the value, the inverse of the longitudinal stiffness, determines the derivative of the function of linear displacement of the wheel center from the tangential traction force when loading it only with normal load. The longitudinal deformation of the tire can be found from the ratio

$$h_X = \frac{H - h_Z}{tg\beta} = \frac{H - h_Z}{\beta}$$

After the transformation, we obtain a dependence connecting the coefficients of tangential λ_T, normal λ_Z and circumferential λ_β, elasticities:

$$\lambda_\tau = \frac{(H/G_K) - \lambda_Z}{M_K \varphi \lambda_\beta}$$

where M_K - is the wheel torque; φ - the coefficient of adhesion of the tire to the support surface. From this expression it is easy to go to the corresponding tire stiffnesses: C_Z, C_β, uC_τ.

The contact deformed bearing surface of the drive wheel has a significant impact on the traction qualities and cross-country ability of the tractor [11]. The area of contact with the soil of tractor tires directly related to normal deformation is determined experimentally on a solid base with normal compression of the pneumatic tire. In the case of an elliptical (or close to it) print, the conditional contact area will be equal to:

$$F_K = \pi a в,$$

where *a* and *b* are the major and minor semiaxis of the ellipse. The values of *a* and *b* can be roughly calculated through the normal deformation and dimensions of the pneumatic tire, using the known geometric relations of the circle:

$$a = \sqrt{h_Z(D - h_2)};$$

$$в = \sqrt{h_2(B - h_2)},$$

In this case, the contact area is

$$F_K = \pi h_2 \sqrt{(D - h_2)(B - h_2)}, \quad (3).$$

Size prints of pneumatic tires, which differs from the ellipse is determined by planetarium. The same method is used to determine the actual contact area of the F_B tire. At the same time, they also determine:

The aspect ratio of the print

$$K_\phi = a/в$$

Saturation coefficients of the tread shape – the activity coefficient of the wheel.

$$K_u = F_в / Fk,$$

A comparison of the results of calculating the contact area of normal deformation (7) with the actual one measured by the pneumatic tire print indicates their discrepancy (Fig.5). Therefore, various correction factors have appeared in the contact area formula, which reflects the geometric relations of the tire parameters. The length of the tire contact, which is included in the mathematical description of the rolling process, can be determined approximately by considering the scheme of the wheel under normal load:

$$2a_{pac} = 2\sqrt{r_c^2 - r_{CT}^2}, \quad (6)$$

However, as the analysis of experimental data showed, the error in this determination of the contact length is on average 25-30 %, depending on the normal load. These errors are a consequence of the previously mentioned mistakes made in the definition of F_k. Therefore, when approximate calculations of the contact length for tractor tires according to the specified formula, it is advisable to enter a correction factor of 0.7 in the right part in the case of tire loading conditions corresponding to the limit values of the ratio h_2/H and 0,75-vice versa.

In this case, formula (6) will have the form

$$2a_{расч} = (0,7...0,75)2\sqrt{r_c^2 - r_{cp}^2}$$

The error in calculating the length of tires of different models based on this relationship does not exceed 10% for tractor tires of different models and trailer tires. Similar calculations were performed in the NGO " NATI" as a result of which an empirical dependence was obtained

$$F_R = 4h_2\sqrt{r_C B}, \qquad (7)$$

by which the conditional contact area of the tire with a solid surface can be calculated with acceptable accuracy. As a criterion for assessing the impact on the soil, the value of the maximum pressure in the contact area of the mover is taken. The permissible level of deformation pressure depends on the soil and climatic conditions, the time of use of the equipment and its features, on the parameters of tires and their operating modes. For a wheel mover with pneumatic tires, the maximum pressure according to GOST is determined from the equation

$$q_K = \frac{m_K g}{10^3 F_K}\sum_{i=1}^{n} K_i,$$

where m_K - is the mass that creates a statistical load on the ground by a single wheel mover, kg; g - is the acceleration of gravity, m/ C^2; - the contour area of the tire contact on a rigid base; K_i - the coefficient.

The coefficients in this formula can be grouped into three main groups:

Depending on operational factors ($1 \le K_i \le 1{,}36$ – on the tire diameter, $1 \le K_2 \le 1{,}5$ - on the uniformity of pressure distribution along the length of the print, $1 \le K_3 \le 1{,}2$ - on the depth of the tread pattern); technological ($0{,}8 \le K_7 \le 1{,}1$ - on the number of passes).

The requirement of GOST for the compliance of the mover with the permissible impact standards is met if the condition is met: $q_K \langle g_{доп}$. Depending on the soil moisture, the limits of change are from 0.8 MPa (humidity less than 0.5 NV in the summer-spring period).

To meet the agrotechnical requirements, it is necessary to analyze the possibility of changing the characteristics of tires and their operating mode (due to changes in $P_Ш, G_R$ and *U*), together with the choice of rational tire models and their configuration for a tractor of another agricultural machine.

In addition, especially for work in areas of increased humidity, it is necessary to create new designs, the so-called agrophilic tires. One of the ways to solve this problem is to develop tire designs of increased

When determining for tractor tires *15,5-38 I-166*, we use the formula 5 and use the obtained data to build a graph 7.

$F_k = \pi h_z\sqrt{(D-h_z)(B-h_z)} = 3{,}14 \cdot 0{,}05\sqrt{(72-0{,}05)\cdot(72-0{,}05)} = 0{,}350$ мм^2

The contact area of a pneumatic tire with the ground is determined by the characteristics of the latter, and in some cases pneumosan contact with the soil is only caused by its deformation (Fig.7). With the increase in the intensity of use of pneumatic tyres has been increasing relations to improve the performance characteristics of pneumatic tires. The ratio of C/V MTA in operation is 0.11-0.80.

X (F_k) мм^2	У$_1$ (h_z) мм	У$_2$ (h_z) мм	У$_3$ (h_z) мм
20	0	0	0
30	400	600	700
40	500	800	900
50	850	950	1100

60	900	1200	1350
70	1100	1400	1500
80	1300	1600	1700

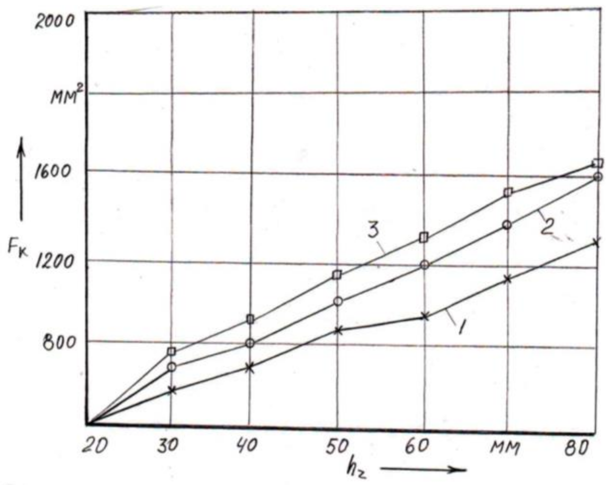

Figure. 6. Dependence of the contact spot area on the normal deformation of pneumatic tires 15.5-38 I-166. 1- experimental; 2 - according to the formula (7); 3 - according to the Hedekel formula

As for diagonal, radial pneumatic tires, the stiffness is almost independent of the normal load, but with increasing air pressure, it increases more intensively. This also indicates a significant dependence of the load capacity of these pneumatic tires on the air pressure in them. Therefore, when using radial pneumatic tires, it is necessary to control this operating parameter more strictly. Up to an air pressure of *0.08-0.10 MPa*, the normal stiffness of a radial pneumatic tire is lower than that of a diagonal tire.

At the same time, the air pressure in the tire has a stronger effect than G_K the coefficient values C_y. Radial pneumatic tires have a lower lateral stiffness, but they have a higher torsional speed, which favorably affects the traction characteristics of these pneumatic tires.

Conclusions:

- reducing the normal stiffness of the tire of this model means increasing its normal deflection, which leads to a decrease in service life. It is established that to ensure normal operating conditions of the tire, the normal deflection should vary in a certain range: (0.11-0.13) N - for tires with a diameter of less than 1.5 m and (0.15-0.2) N - for tires with a diameter of more than 1.5 m.

- due to the increasing intensity of operation of pneumatic tires, there is a tendency to increase the ratio to improve the performance of tires. The *C/B* ratio of agricultural machinery in operation is 0.10-0.82.

- usually, tractor tires have no more than 30% of the total area of the contact spot.

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