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The Dynamic Characteristics of the Tires of the Wheels of the Tractor

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Abstract:
The monograph discusses the basic position of the running system of the machine-tractor unit during operation to ensure the reliability of the tractor, the main factors affecting the operation in pneumatic wheeled tires and the choice of the use of construction materials depending on work processes, providing technological capabilities and constructive durability of pneumatic tractor tires tractor wheels.
Keywords:operational factor, agrotechnical indicators, tractor patency, relative deformation, towing properties, soil loads, air pressure, wear rate, average resource

I. INTRODUCTION

One of the main tasks of modern agricultural production is to increase output based on the comprehensive mechanization of all processes.

To perform these tasks, it is necessary to equip agricultural production with machines of the greatest possible productivity, which have high reliability and durability during operation.

Currently, there is a system of machines for all cotton cultivation and harvesting, and it is also being developed in the future, where almost all the work is assigned to the row-crop tractors with a complex of agricultural machines. Tillage tractor, as a mobile power industry, operates under various loads, both in terms of load capacity and traction.

The main operational and agro-technical qualities of a row tractor are characterized by the capabilities of their driving wheels, in particular by their tires. Pneumatic tires are manufactured for tractors and agricultural machines in accordance with GOST 7463-2003 [7]

II. SYSTEM DESCRIPTION

The influence of the deformation of the tractor's patency tire on the kinematic discrepancies of the driving and driven wheels. The tiller drive is mainly used on domestic and foreign wheeled tractor models. One of the features of this drive is the possibility of kinematic discrepancy due to both the design of the tractor, in particular, the models of its tires, and operational factors.

The calculated dependences of the kinematic mismatch coefficients on the relative deformation of the front wheel tires for MTZ-80X and New Holland TD5 110 tractors when they are equipped with tires of various models [10, 11, 12].

It is known that when designing new tire models for which there are no experimental dependences of the normal deflection on the load and air pressure in the tire, the kinematic mismatch coefficient can be approximately determined by the dependence:

$$K_H = 1 - \frac{i_2 r_{C1}}{i_1 r_{C2}},$$

Where r_{C1} and r_{C2} - are the free radii of the tire wheels of the front and rear.
The exact result is obtained when calculating by the formula:

$$K_H = \left[1 - \frac{i_2 r_{K1}^C}{i_1 r_{K2}^C}\right] 100\%.$$

The experiments were carried out with a forced-locked freewheel on two road-soil backgrounds: a field prepared for sowing; loam; hardness of 0.8-1.1 MPa, humidity at a depth of 0.1 m was 10-13%, air pressure in the front tires is 0.1 MPa, in the rear 0.08 MPa.

The dependence of the $K_H$coefficient on the relatively normal deflection of the tires of the front (h_{Z1}/H_1) and rear (h_{Z2}/H_2) wheels was obtained by comparing the free radii $r_к$of the tires calculated by the formula of Ya. S. Agaykin [1]. Since h_2/H is a function of the values of $P_ш$ and G_K, the graphs actually show the range of changes in the value of K_H from the main operational factors.

Analysis of the research results shows that the value and sign of the kinematic mismatch coefficient are mainly determined by the free tire diameter and gear ratios of the bridges. Arbitrary tractor equipment with tires with different free diameters causes sharp fluctuations in the kinematic mismatch coefficient (from +15% to –14%).

A change in the relative deflection of pneumatic tires by ±100% of the norm leads to a change in the value of $K_H$by 2%, the tolerance on the free diameter of the tire has the same effect. The redistribution of gravity between the front and rear wheels when operating the tractor with a hook load does not significantly (by 1.0-1.5%) reduces the positive value of the kinematic discrepancy and increases its negative value.

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For MTZ-80X and New Holland TD5 110 tractors, a set of tires can be pre-selected based on the condition that the ratio of the free diameters D_1 and D_2 of the tires of the front and rear wheels should be $D_1 / D_2 = 0.64$. The following tire configurations satisfy these conditions: 9.5–42 Я-183 and 13.6 R38 ЯР – 318 ($K_н$= + 2%); 11.2-42; 14.9R24 8PR and 15.5-38 I-166 (K_H = + 1.7%); 8.2-20 and 18.4 / 15-30 R-19; 18.4 R34 TR-135 10PR (K_H = -1%). Fora more complete assessment of the influence of tire parameters and their configuration on the traction and hitching properties of the tractor and MTA, we will calculate the estimated indicators of these properties according to the developed mathematical model [3,4].

MTA design scheme (Figure1), the generalized coordinates are as follows: x_c; y_c; z_c; z_1; z_2; φ_1; φ_2; φ_3; φ_4. The dynamic movements of the MTA, taking into account the characteristics of pneumatic tires, will be obtained on the basis of the general Lagrange equation of the first kind with indefinite factors:

$$\ddot{x}_c = \frac{1}{M_0}\left[\sum_{i=1}^{n=4} K_{yi}\nu_i \sin(\varphi_1 + \Theta_1 - \gamma_i) + \sum_{i=1}^{n=4} P_{gi}\sin\Theta_i \sin\varphi_1\right];$$

$$\ddot{y}_c = \frac{1}{M_0}\left[\sum_{i=1}^{n=4} K_{yi}\nu_i \cos(\varphi_1 + \Theta_1 - \gamma_i) + \sum_{i=1}^{n=4} P_{gi}\cos\Theta_i \cos\varphi_1\right];$$

$$z_c = \frac{1}{M}\left(C_3\Delta_3 + C_4\Delta_4 + \alpha_3\dot{\Delta}_3 + \alpha_4\dot{\Delta}_4\right);$$

$$\ddot{z}_1 = \frac{1}{m}\left(C_1\Delta_1 + \alpha_1\dot{\Delta}_1\right); \ddot{z}_2 = \frac{1}{m}\left(C_2\Delta_2 + \alpha_2\dot{\Delta}_2\right);$$

$$\varphi_1 = \frac{1}{I_1}\{K_{y1}\gamma_1[B\cos(\Theta_1 - \gamma_1) + 0{,}5B\sin(\Theta_1 - \gamma_1)]\}$$
$$+ K_{y2}\gamma_2[B\cos(\Theta_2 - \gamma_2) + 0{,}5B\sin(\Theta_2 - \gamma_2)] -$$
$$- K_{y3}\gamma_3[B\cos(\Theta_3 - \gamma_3) + 0{,}5B\sin(\Theta_3 - \gamma_3)] -$$
$$- K_{y4}\gamma_4[B\cos(\Theta_4 - \gamma_4) + +0{,}5B\sin(\Theta_4 - \gamma_4)] +$$
$$+ \sum_{i=1}^{n=2} P_{gi} b\sin\Theta_i - \sum_{i=3}^{n=4} P_{gi} b\sin\Theta_1 + P_{KP1}l_1 + P_{KP2}l_2 +$$
$$\sum_{i=1}^{n=4}(M_{yi} + M_{C\Pi i})\};$$

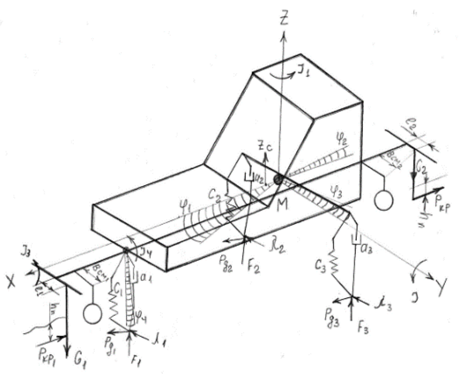

Figure 1- Design scheme for the movement of universal row-crop tractor units.

$$\ddot{\varphi}_2 = \frac{\Pi_2}{I_2}\left(C_3\Delta_3 + C_4\Delta_4 + \alpha_3\dot{\Delta}_3 + \alpha_4\dot{\Delta}_4\right);$$

$$\ddot{\varphi}_3 = \frac{\Pi_1}{I_3}\left(C_4\Delta_4 - C_3\Delta_3 + \alpha_4\dot{\Delta}_4 - \alpha_3\dot{\Delta}_3\right);$$

$$\ddot{\varphi}_4 = \frac{1}{I_4 + 2mh_\delta^2}\left(C_2\Delta_2 - C_1\Delta_1 + +\alpha_2\dot{\Delta}_2 - \alpha_1\dot{\Delta}_1\right);$$

Where $M_0=M+2m;$ $\Delta_1=F_1-Z_1;$ $\Delta_2=F_2-Z_2;$ $\Delta_3=F_3+\varphi_3\Pi_1-\varphi_2\Pi_2-Z_C;$ $\Delta_4=F_4+\varphi_4\Pi_1-\varphi_2\Pi_2-Z_2.$

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The equations of kinematic relations, provided there is no slip of the tractor wheels in the direction perpendicular to the resulting tractor speed, are as follows:

$$\gamma_1 = arctg\left[\frac{A_1 - \dot{\varphi}_1(b \cdot \cos\Theta_1 + 0{,}5B \cdot \sin\Theta_1)}{S_1 + \dot{\varphi}_1(b \cdot \sin\Theta_1 - 0{,}5B \cdot \cos\Theta_1)}\right];$$

$$\gamma_2 = arctg\left[\frac{A_2 - \dot{\varphi}\ (b \cdot \cos\Theta_2 - 0{,}5B \cdot \sin\Theta_1)}{S_2 + \dot{\varphi}_1(b \cdot \sin\Theta_2 + 0{,}5B \cdot \cos\Theta_2)}\right];$$

$$\gamma_3 = arctg\left[\frac{A_4 + \dot{\varphi}_1(a \cdot \cos\Theta_4 - 0{,}5B \cdot \sin\Theta_4)}{S_4 - \dot{\varphi}_1(a \cdot \sin\Theta_4 + 0{,}5B \cdot \cos\Theta_4)}\right];$$

$$\gamma_4 = arctg\left[\frac{A_4 + \dot{\varphi}_1(a \cdot \cos\Theta_4 - 0{,}5B \cdot \sin\Theta_4)}{S_4 - \dot{\varphi}_1(a \cdot \sin\Theta_4 + 0{,}5B \cdot \cos\Theta_4)}\right];$$

Где $A_i = \dot{x}_c \sin(\varphi_1 + \Theta_i) - \dot{y}_c \cos(\varphi_1 + \Theta_i);$

$$S_i = \dot{x}_c \cos(\varphi_1 + \Theta_i) + \dot{y}_c \sin(\varphi_1 + \Theta_i).$$

Devices for measuring the deformation of pneumatic tires of a tractor wheel. To measure tire deformation in dynamics, we developed and applied the installation (Figure 2). The device and the principle of operation of the device is as follows. The system includes a frame, plates of metal material, indicators of the watch model, a stop with lowering the tractor and a mechanism for guiding the tractor wheel.

Figure 2- The indicator of the clock model *ICh-150* (tire pressure 0.10 MPa) of the driving wheel 13.6 R38 ЯR-318 for determining the deformation properties: 1-fixed frame (installation frame); 2-locking bolt; 3-tensile resistant; 4-movable support (plate).

Figure 3- Drive wheel 18.4-34 TR-135 10PR New Holland TD5 110 for determining deformation properties using the indicator of the watch model ICh-150 (tire pressure 0.10 MPa)

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The analysis of the given dependences shows that with an increase in the load on the soil, there is a decrease in slippage and an improvement in the deformation properties of tractor tires.

Based on the dependences of the normal deflection on the normal load, the corresponding stiffness factors are determined. In the field of workloads, where the load characteristic is almost linear, and stiffness shows that little depends on the load.

The dependence of the coefficient of normal stiffness on air pressure for row tractor pneumatic tires is shown in Figure 6. The coefficient of normal stiffness increases with increasing air pressure almost proportionally.

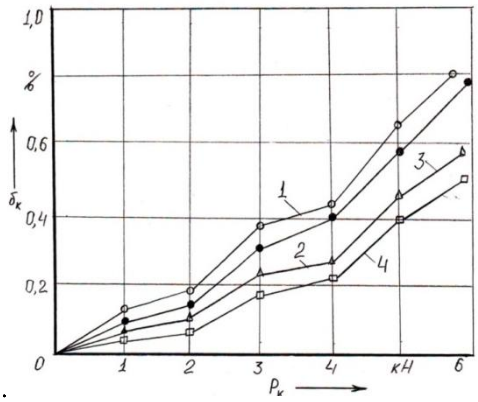

Figure 4- The dependence of the lateral movement of pneumatic tires 13.6 / R38 ЯR-318 on the lateral force at various normal loads (P = 0.15 MPa):

1).$G_к$ =14 кН; 2).$G_к$=12 кН; 3).$G_к$=10 кН;

4).$G_к$=8 кН.

Experimental values are shown in graphs 1,2,3,4; --- • --- values calculated by the formula:

$$h_y=8,73-55,7\,p-0,4G_кP+8,2P_y+0,16P_y^2$$

$F_k=\pi h_z\sqrt{(D-h_z)(B-h_z)}=3,14\cdot0,05\sqrt{(72-0,05)\cdot(72-0,05)}=0,350$ мм^2

The contact area of pneumatic tires with soil is also determined by the characteristics of the latter, and in some cases, the contact of pneumatic tires with soil is caused only by its deformation (Figure 5).

With the increasing intensity of operation of pneumatic tires, there is a tendency to increase the ratio to improve the performance of pneumatic tires. The C / V ratio of MTAs in operation is 0.11-0.80.

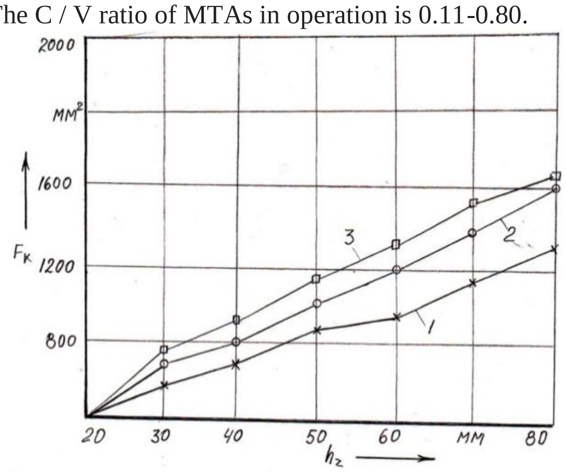

Figure 5- Dependence of the contact spot area on the normal deformation of pneumatic tires 15,5-38 I-166. 1-experimental; 2 according to the formula;

3- according to the Hedekel formula

In the tire, air pressure in this case also has a stronger effect than the coefficient values. Radial pneumatic tires have lower lateral stiffness, but they have higher torsional speed, which favorablyaffects the traction characteristics of these pneumatic tires. The load capacity of the tire is the largest allowable value of the normal load - Q extra at which, despite the radial deformation - w,the specified service life of the tire is ensured for a given value of air pressure in it.

Thus, our analyzes show hysteresis losses proportional to the total losses on rolling resistance (tractor speed, traveled path S ≈ 1.5 α (α is the contact area), tire types, tire air pressure, strain values, lateral force, tread thickness and other) tractor tires.

Determine the probability of failure-free operation of tractor tires for 1000 hours if its MTBF is described by theWeibull distribution with parameters a = 2 and $\lambda = 6.592 \cdot 10^{-7}$.

The probability of failure of tractor tires is

$P(t) = 1-F(t) = e^{-\lambda ta} = e^{-6.667\cdot10\text{-}7\cdot10002} = 0.480$.

Therefore, the probability of failure of tractor tires for 1000 hours is 48.0%.

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The random operating hours of tractor tires to failure are distributed according to Weibull law with parameters a = 2, $\lambda = 10^{-6}$. Find the probability of failure of tractor tires for a given operating time T_{γ} = 250 hours.

We use the formula to calculate the probability of uptime in the Weibull distribution

P (300) = $e^{-\lambda \cdot T\gamma a} = e^{-10\text{-}6 \cdot 3002} = -e^{-10\text{-}6 \cdot 9 \cdot 104}$ = 0.9057.

Therefore, the probability of failure of tractor tires for 250 hours is 90.57%.

For the previous example, find tractor tires running to failure with a 99%probability of failure-free operation. The graph shows that the distribution of the function *F(t)* and the probability of failure-free operation *P(t)* are shown in Figure 6, with an increase in *F(t),* the indicators *P(t)* decrease and vice versa.

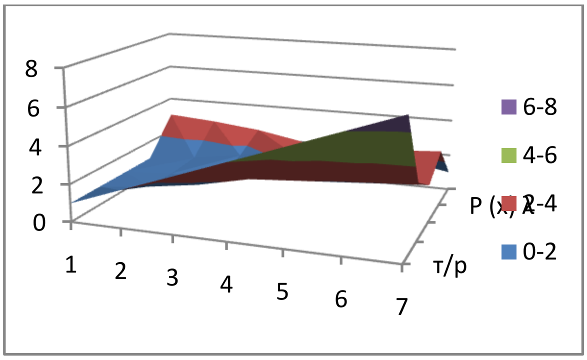

Figure 6 - Graph of the distribution functions *F(t)* and the probability of uptime *P(t)*

Use the probability equation for uptime

0.99 = $e^{-10\text{-}6 \cdot T\ 99\%\ 2}$, whence ln0.99 = $-10^{-6} \cdot T_{99\%\ 2}$,

Therefore, $T_{99\%} = \sqrt{\text{In}0.99 / -10^{-6}}$ = 100 hours

Lifting capacity of universal row-wheel tires. In most cases, pneumatic tires are chosen and load capacity is calculated based on the indicators of their static load, determined by weight characteristics, MTA - this principle is laid down in the standards that are in force in our conditions, as well as in international ISO recommendations [4,7,13].

In operating conditions, a number of approximate formulas are used to calculate the load capacity of pneumatic tires, depending on operational factors. The most widely used formula was R. Hedeckel.

$$G_K = \pi p_{ш} h_Z \sqrt{BD} \quad , \qquad \textbf{(1)}$$

V. L. Giterman proposed an empirical relationship to determine the carrying capacity:

$$G_K = RB^2 \qquad (2)$$

where R -is the load factor.

Ya. S. Ageykin [1,4] suggested the dependence:

$$G_л = \frac{\pi^2}{4} h^2 (P_ш + P_c) \left(\frac{B}{H} + \frac{3H}{2B} \right) \left(1 - \frac{h_2}{2B} \right) \sqrt{Dh_2 - h_z^2} \qquad (3)$$

where P_0- is the component pressure from the stiffness of the shell.

This equation is appropriate for thin-walled tires. The absence of parameters in the technical characteristics makes it difficult to apply this formula.

The estimated load capacity of the tire can be determined by the empirical Hell formula:

$$G_K = 0{,}11 P_ш^{0{,}585} B_T^{1{,}39} (d_n + B_T) \qquad (4)$$

Where d_n- is the landing diameter of the rim; B_m-the theoretical width of the tire profile, reduced to the ideal rimB_m= 1.4-0.64 *C*. Here *C* - distance between rim flanges (flange solutions).To establish a common relationship between

$$h_2, C_2, G_R, P_ш,$$

as the initial approximating dependence of the experimental data $C_2 = f(P_ш)$ The model of linear regression of the species was adopted.

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$$C_2 = a_1 + a_2 p_ш \quad (5)$$

Where a_1, a_2 -accordingly, the coefficients characterizing the normal rigidity of the frame and the increase in normal rigidity per unit pressure. Then $h_Z = G_K / (a_1 + a_2 P_ш)$

Given that the permissible value of the relative deformation for the tires of the front wheels of universal row-crop tractors is 0.11-0.13, and for the rear - 0.17-0.19 their load capacity can be determined from the expressions

$$G_{К.П} = 0{,}12H \ (a_1 + a_2 p_ш),$$

$$G_{К.З} = 0{,}18H \ (a_1 + a_2 p_ш),$$

Where $G_{К.П}, G_{К.З}$ - accordingly, the load capacity of the front and rear wheels.

For the front wheels of the MTZ-80X tractor, we determine from formula (5) and from the obtained data we construct a graph.

$G_{к.п} = 0{,}1 \cdot H(\alpha_1 + \alpha_2 p_ш) = 0{,}1 \cdot 0{,}294 \ (0{,}12) =$

$= 0{,}007056 = 7{,}0$ кН

depending on the load from the formula

$h_z = G_k / (\alpha_1 + \alpha_2 \, p_ш)$:

$\alpha_1$andα_2 – the coefficients of the normal stiffness frame of tractor tires, we take from the table [5], it is equal to$\alpha_1 = 110{,}1$ и$\alpha_2 = 1032$, при

$P_ш = 0{,}12$.

$h_z = G_k / (\alpha_1 + \alpha_2 \, p_ш) = 0{,}18 \cdot H(\alpha_1 + \alpha_2 \, p_ш) = 0{,}18 \cdot 0{,}394 \ (110{,}1 + 1032 \cdot (0{,}12)) = 0{,}070 \ (233{,}94) = 8{,}66 = 0{,}866$ кН:

$h_z = 8{,}66/0{,}12 = 1{,}040$ кН.

Thus, the abnormal rigidity of the carcass of tractor tires with*$P_ш = 0{,}12$ $h_z = 1{,}040$ кН,*considered closer to theoretical.

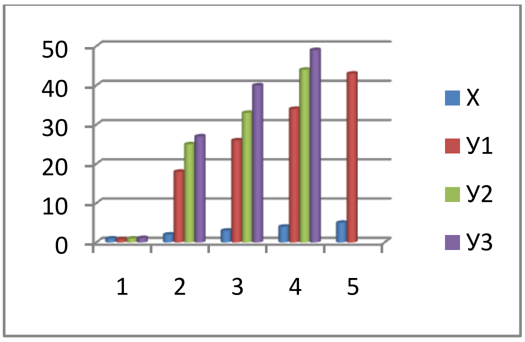

Figure 7- The dependence of the normal deflection of the frame on the normal load for row tractor tires (Rш = 0.12):1). 9,5-42 Я-183; 2). 13,6 R38 ЯР-318; 3). 15,5-38 Я-166.

The dependences of the tire carrying capacity on air pressure calculated according to the given dependences [6] and constructed according to GOST are almost identical. A slight difference is due to the fact that the calculations use the value of the relative deflection.

With this approach, one can judge the degree of congestion of existing tires and the possibility of their effective operation, the reserves of carrying capacity and the possibilities of working under reduced pressure.

The tire 9.5-42 Я-183 turned out to be very sensitive to changes in the coupling load. Less wider tires are less sensitive to changes in traction. On the 13.6 R38 ЯR-318 tire, an increase in the grip load to the maximum permissible reduced the amount of slipping by only 5%.

The tire 18.4/15-30 R-319 also turned out to be significantly slightly sensitive to load changes: the difference in the amount of slipping is only 4%. It should be noted that a similar difference in the value of slipping is observed with an increase in traction force P = 12753 N, the difference in slipping on a tire 9.5-42 Я-183 increases by 3-4%. At tires *13,6R38 ЯР-318* и *18,4/15-30 R-319* на *2-3 %.*

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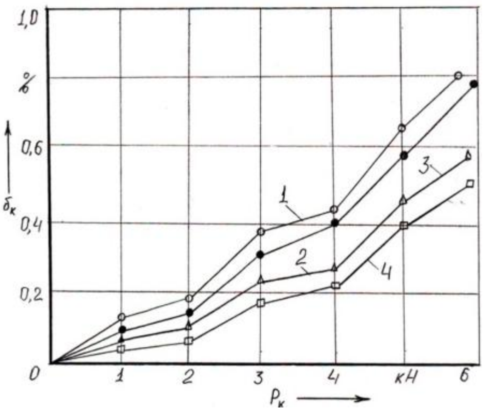

Figure 8 - The dependence of the tangential traction on the slipping of tractor pneumatic tires (stub P_{sh} = 0.1 MPa):1).*9,5-42Я-183*; 2).*13,6R38 ЯР-318*; 3).*15,5-38 Я-166*; 4).*18,4/15-30 R-319*.

The Figure shows the slippage versus tangential traction for *9,5-42 Я-183; 13,6R38 ЯР-318, 15,5-38 Я-166 и 18,4/15-30 R-319*obtained on the crease surface is similar to that used in the calculations. It clearly shows an improvement in traction performance of the tire with an increase in its width

Interesting results were obtained when analyzing the dependence of slippage on developed traction.

For comparison, a permissible slipping value of b = 20% was chosen. A tire 9.5-42 I-183 with such a slippage value develops 3 traction forces P = 11438.5 N, a tire 13.6R38 ЯР – 318-12419.5 H, a tire 18.4 / 15-30 R-319 –12900 N. Therefore, with b = 20% and the same amount of grip, wider tires contribute to an increase in the developed traction force.

Our studies show tire spots in various cotton treatments:

А)

Б)

В)

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Our studies show tire spots in various cotton treatments:

a)

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б)

в)

Figure 9- Spots of 18.4 / 15-30 R-319 tires at
various loads:

a) tractor without an aggregate; b) a tractor with a cultivating unit; c) tractor with fertilizer cultivator.

Figure 10- Spot measurements of tractor pneumatic tires under various loads: a) tractor without an aggregate; b) a tractor with a cultivating unit; c) tractor with fertilizer cultivator.

Define the uptime of a batch of tires in quantity

N = 100 pcs., Which should have an operating time of x80 = 5000 hours (they must maintain working capacity of at least 80% (according to academician Sh. U. Yuldashev). It is known that within 5000 hours of their work failures: one bus after 3000 h, two tires after 4000 hours and one tire after 4500 hours
In accordance with the accepted designations x80 = 5000 h, N1 = 14 and N11 = 86; total operating time
∑xi = 3000 + 2 • 4000 + 4500 + 86 • 5000 = 44.55 • 104 hours

Using approximate formulas (5.8), (5.10) and (5.11) (Prof. G. B. Iosilevich) we find Q (x1) = 0.04; P (x1) = 0.86; and xav = 31 • 103 hours

Thus, the probability of tire failure was 86%, i.e. above the specified equal to 80% (Figure 17).

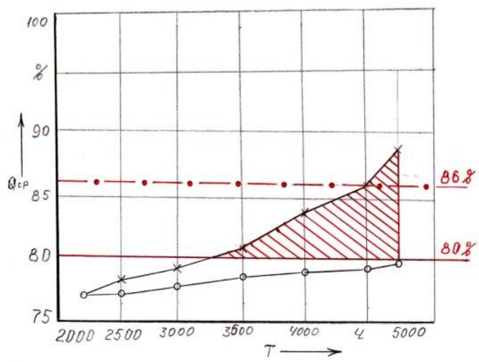

Figure 11- changes in the intensity of the average resource depending on the operating time:

1-existingoption; 2 proposedoption.

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By the formulas (13), one can also determine the magnitude of the failure rate for all batches of tires on average for the operating time x80. Setting Δx = x80, ΔN = N1, we obtain λ (x80) = 0.8 • 10-5.

For an approximate determination of reliability, you need to know their operating time to failure or until the end of the test: x_1, x_2 ..., x_n

During observations in operation are determined by the methods of Iosilevich G.I. approximate values for uptimeby which it is possible to evaluate their exact values obtained by the above formulas.

- The average resources are 15.5-38 I-166 and 18.4 / 15-30 R-319 tractor tires, the probability of tire failure was 82.4%, i.e. above the specified equal to 80%.
- The performance calculation shows that the tires (front 12-16 and rear 18.4 / 15-30 R-319 tires) account for 86.2%.

The horizontal plane - we determine the support reactions, N.

$\Sigma M_3 = Q$; $F_м L_м + \frac{Ft1\,Lb}{2} - R_{ax} L_b = 0$;

$$R_{ax} = F_м L_м + \frac{FmLm + Ft1\,Lb}{2} = 53{,}1H \cdot 4{,}4 \cdot 10^{-3} м + 1100\ H \cdot 100 \cdot 10^{-3} м / 200 \cdot 10^{-3} м = 666{,}82\ H;$$

$$\Sigma M_1 = Q;\ -R_{bx} L_b - Ft_1 L_b/2 + F_м (L_м + L_b) = 0;$$

$R_{bx} = -Ft_1 L_b/2 + F_м (L_м + L_b)/L_b = -1100\ H \cdot 100 \cdot 10^{-3} м + 531\ H \cdot 244 \cdot 10^{-3} м / 200 \cdot 10^{-3} м = -110000\ H + 12956\ H/200 = 97{,}82\ H$;

- We plot the bending moments with respect to the Y axis in characteristic sections 1–4, N /m; $\Sigma M_{y1} = Q$; $M_{y2} = -\frac{Ra\ Lb}{2}$; $M_{y4} = 0$; $M_{y3} = -F_m L_{on}$.

-construct a plot of torques, *N.m*

$M_n = M_z = \frac{Ft1\,d1}{2} = 1100\ H \cdot 40 \cdot 10^{-3} м/2 = 22\ H \cdot m$;

Determine the total radial reaction, *N*

$$R_a = \sqrt{Rax^2 - Ray^2} = 670{,}484\ H;$$

$$R_a = \sqrt{Rbx^2 - Rby^2} = 1892{,}52 H.$$

- Determine the total bending moments in the most loaded sections, N · m; $M_z = \sqrt{Mx^2 - My^2} = 1821 H$. $M_3 = M_{y3}$

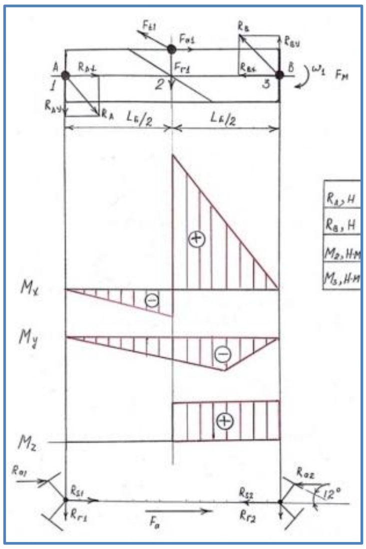

Figure 12- Design diagrams of the drive wheel of the tractor "New Holland"

The values of bending, torques and total radial reactions are obtained from the source data.

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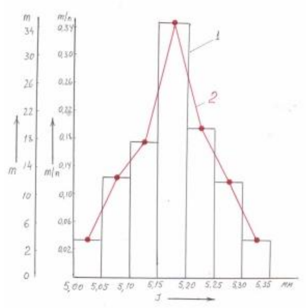

Figure 13- Distribution of measured tread wear of tractor (13.6 R38 ЯR-318) tires:
1-bar distribution; 2 empirical distribution curve

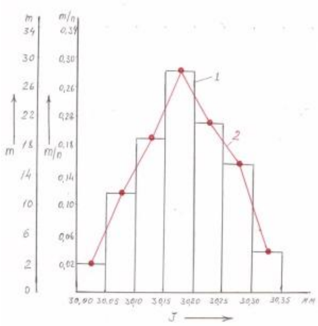

Figure 14- Distribution of the measured dimensions of the wear of the tread of tractor (9.5-42 I-183) tires:
1-bar distribution; 2-empirical distribution curve.

Mass and inertial characteristics of pneumatic tractor tires. The geometrical dimensions of universally tilled wheeled tractor tires, standardized in standards, international directories, recommendations and given in the catalogs of the manufacturers of the plant. Typically, the nominal values of the outer diameter and the maximum possible values of the profile width are given [4.7]

For tires 12-16 L-163, B is set to no more than 326 mm for the main rim W11 / W8; 8.00V and for permissible rims: W 9 - no more than 270 mm, W7 - no more than 254 mm. In a number of regulatory documents, the value of the static radius r_{st}, 12-16 L-163 tires r_{st} = 400 mm is standardized.

When changing materials in tire production, an increase in tolerance r_{st} of ± 2.5% is allowed.

Our analyzes show that the tire sizes for the front or driving wheels of the tractors, where it can be seen that for the same tire section there are several rim width values, due to the range of relative size values and the requirement to set the rim width in whole inches (Figure 15). But still, the tire of a certain model should be installed on the rim of the desired width. In this case, you can get the best tire performance [12].

a)

б)

Figure 15- Determining the rim width of the front wheels of the New Holland TD5 110 tractor:
a) front view; b) side view.

Changes in the board solution distance change the tire cross section and its characteristics (Figure 16), which affects the tire’s working condition. So, when installing the tire on a narrower rim, the radius of curvature of the treadmill decreases. As a result of this, the width of the tire’s contact with the soil and, accordingly, the tractive effort will decrease, and the wear rate in the central zone will increase.When installing the pneumatic tire on the rim, the width of which is greater than the recommended, the contact load will concentrate on the outer shoulder areas of the treadmill, which will lead to increased wear in these places and increased material loading

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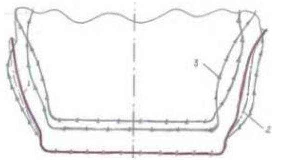

Figure. 16- Change tire profile gauges*12-16 Л-163*when installing it on*W11/W8;8.00V*rims:
1-P_w*=1,5кгс/см*^{2} *(0,15 МПа)*; 2- P_w*=0,9 кгс/см*^{2} *(0,09 МПа)*; 3- P_w*=0,4 кгс/см*^{2} *(0,04 МПа).*

When changing the tire profile, according to the weight of tractor tires in international standards, recommendations, as a rule, are not standardized and are not given. The difficulty with the standardization of mass indicators lies in significant changes in the mass characteristics of the tire materials themselves. The density of the rubber $\gamma_р$ = 1.12-1.15 kg/cm^3, significantly change

III. SIMULATION RESULTS

Determination of the tread wear rate of a tilled wheeled tractor in cotton processing conditions. Currently byagricultural engineering thereare methodological, mathematical and procedural developments that can significantly reduce the cost of laboratory and production experiments, based on the use of expensive prototypes of the tested equipment and significant investment in completing the technical support of experiments[13]. Estimating the relevance level during the implementation of search and research procedures, we note that it is not enough to use one of the existing methods to analyze the influence of the steering angle on the tire wear rate of a tractor when moving along a two-sided inclined (egate) supporting surface during cotton processing

As a result of the study, an empirical relationship was obtained that determines the wear rate of tires of pneumatic wheels interacting with a horizontal supporting surface [1]:

$$I=K_i P_{ср}\, \mu_{тр}\, a\delta_i/2\pi\, r_к \quad (6)$$

WhereK_i- coefficient of abrasion ability of the soil;$P_{ср}$ -average nominal pressure in contact, *МПа*; $\mu_{тр}$- coefficient of friction of rubber on soil; δ_i -wheelanglei, *рад;*$r_к$ -wheelradius, *м*; a -wheel contact spot length, m.
This technique has a limited research range. It is necessary to establish additional theoretical, formal relationships and mathematical expressions of its empirical components. It was established that the deformed contact spot of the wheel has a significant impact on the tractor's handling [1]. The area of the contact patch of tractor tires directly related to normal deformation is determined by the elliptical imprint of the tire contact. The semi-major axis of the ellipse is half the length of the tire contact spot [5]:

$$a = 2\sqrt{r_{ст}{}^2 + r_c^2}, \ (7)$$

where rst is the static radius of the wheel, m; r_c- is the free radius of the wheel, m

The Scientific Research Tractor Institute OJSC made adjustments and developed reliable methods for determining structurallypropulsion mode parameters, including contact spot length. In this regard, a refinement coefficient is found in equation (7), which isranging from 0.7 to 0.75 [6]:

$$a = (0,7...0,75)2\sqrt{r_{ст}{}^2 - r_c^2} \ (8)$$

In the obtained expression (8), the difference between the free and static radius characterizing the normal deflection of the tire hz is of research interest [4]. Thus, the expression of the tire contact length can be converted into a formula that is convenient for further mathematical procedures for determining tire wear:

$$a = 2(0,7...0,75)\sqrt{h_z^2} = (1,4...1,5)\, h_z, \qquad (9)$$

where hz - is the normal deflection of the tire, m. To find the normal deflection, there are a number of empirical expressions [2,4]. Reliable, according to leading experts, is the technique proposed by R. Hedekel. It takes into account both the internal pressure and the angle of inclination of the supporting surface

$$h_z = \frac{G\cos\alpha}{\Pi p_{\omega}\sqrt{Db_K}} \ (10)$$

Where$b_к$– wheel width, m; D - wheel diameter, m.

As provided in the methodology of V.P. Boykova [3,4] and I.V. Asmankin [2], when the wheel is working on an inclined support surface, tire wear has a specific character associated with the influence of the slip angles on tire deformation. However, the authors did not establish themathematical dependence of the determination of the angle of withdrawal, but designated it

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as an empirical parameter that cannot be expressed without real laboratory and production experiments. In this regard, the costs of scientific and technical research are increasing in the segment of creating a physical prototype.In fact, we are talking about the advisability of an analytical approach to solving the issue of forming an array of the desired values instead of expensive measuring procedures.Thus, the method of calculating the steering angle using the ratio *Gsinα* to the expression $(C_{1\ p\omega 1,2}Gsin\alpha + C_{2p\omega 1,2}Gcos\alpha)$ is of particular interest for theorizing the intensity of tire wear when the tractor unit moves along an inclined supporting surface during cotton processing.

During the study, it became necessary to determine the average nominal pressure in the tire contact patch with the supporting surface P_{av}, which is expressed as the ratio of the normal force component N and the contact spot area $F_{пк}$. The values of the normal force components differ depending on the location of the wheels relative to the longitudinal and transverse axes of the tractor. Normal force component of the front wheel, right rear wheel, left rear wheel [2]respectively equal, *N*:

$$N_{ппк}=0,4\ G\ (\frac{\cos\alpha}{2}+\frac{h}{B}sina);$$

$$N_{пзк}=0,6,\ G\ (\frac{\cos\alpha}{2}+\frac{h}{B}sina);$$

$$N_{лзк}=0,6\ G\ (\frac{\cos\alpha}{2}+\frac{h}{B}sina); \quad (11)$$

where *h*- is the height of the center of gravity of the tractor, m; *B* - wheel gauge, m.

It is permissible to consider the power load in the longitudinal plane. The total reaction from the supporting surface to the rear wheels will change by ΔN_z, respectively.

$$\Delta N_з + P_{кр}h_{кр}sin\tau + P_{кр}cos\tau(m+0.6l) = 0$$

Where from

$$\Delta N_з = \frac{P_{кр}(h_{кр}sin\tau + cos\tau(m+0.6l))}{l}$$

Thus, we obtain the equations of the normal force components taking into account the hook load:

- component of the normal power of the right rear wheel, *N*:

$$N_{пзк}=0,6\ G\ (\frac{\cos\alpha}{2}+\frac{h}{B}\ \sin\alpha)+\frac{P_{кр}(h_{кр}sin\tau+cos\tau\ (m+0,6l))}{2l}(2)$$

– component of the normal power of the left rear wheel, N

$$N_{лпк}=0,4\ G\ (\frac{\cos\alpha}{2}-\frac{h}{B}\ \sin\alpha)-\frac{P_{кр}(h_{кр}sin\tau+cos\tau\ (m-0,4l))}{2l}(13)$$

The contact spot area $F_{пк}$is expressed as follows, m^2:

$$F_{пк} = \pi\ b_{пк}a\ /\ 4 \qquad (14)$$

Where$b_{пк}$– wheel contact spot width, m;

Necessary to determine the intensity of wear in the method of V.P. Boykova such parameters as the coefficient of abrasion ability of the soil

Ki, the coefficient of friction of rubber on the ground μ_{mr}, the rolling radius of the wheel r_k, are reference data for each specific tire model [3,4]. At the suggestion of I. V. Anisinkin [2], that the tread wear rate per unit length of the path of a pneumatic wheel under conditions of inclined farming and the presence of hook load is described by the expression:

$I= 2K_i\ N_i\mu_{mp}Gsin\ a\ /\ r_к b_{пк}\pi^2\ (C_1+C_2p_{\omega 1,2}Gcos\alpha)(15)$

Our analysis shows that the tread wear rate per unit path length of a pneumatic wheel in cotton farming during cotton processing and the presence of a hook load is described by the expression:

$$I= 2K_i\ N_i\mu_{mp}Gsin\ a\ /\ r_к b_{пк}\pi^2\ (C_1\ p_{\omega 1,2}Gsin\alpha + C_2p_{\omega 1,2}Gcos\alpha)(16)$$

The obtained technique made it possible to analyze the magnitude of the force interaction of the tire with the supporting surface during its deformation and slipping in the contact spot, which under the conditions of lateral withdrawal is a characteristic of the wear rate. Given the possibility of a numerical solution of the analyzed system of equations, further formalization of the search procedures is carried out in the format of a mathematical experiment taking into account its machine interpretation in the MathCAD program.

R_{kr}-hook force, *N*; h_{cr}- is the height of the application of the hook force; *m* - is the distance between the hook force and the center of gravity of the tractor; *l*- is the distance between the axles of the front and rear wheels; Z, P - interaction points, respectively, of the rear and front wheels with the supporting surface; ↓- is the gradient of the slope; τ– angle of inclination of the hook force, rad.

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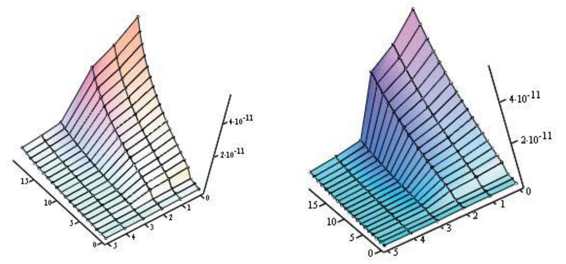

а) б)

Figure 17- Tire intensity function as a function of internal pressure on the egat slopes: a-rear left wheel with tire

18,4/15-30 R-319 ,
$P_{w2}=10^6$Па;
b-rear right wheel with tire
18,4/15-30 R-319, $P_{w3}=10^6 Па$

R_{kr}-hook force, N; h_{cr}- is the height of the application of the hook force; m is the distance between the hook force and the center. For mathematical modeling of tire wear (Figure17), it is advisable to use the parameters of the MTZ-80X tractor taking into account its configuration with 18.4/15-30 R-319 model tires, respectively, of the rear wheels. That is, the conditions were accepted: m tractor severity; l is the distance between the axles of the front and rear wheels; Z, P - interaction points, respectively, of the rear and front wheels with the supporting surface; ↓ is the gradient of the slope; τ– angle of inclination of the hook force, rad.
p_ω= [*0,08 МПа; 0,2 МПа*]; α= [0^0; 15^0]; *G =3150 кг.* $\mu_{тр}$= 0,07; $C_1^{пер.к}=24{,}8$; $C_2^{пер.к}=10{,}3$; $D^{пер.к}=985$ *мм;* $b_к^{пер.к}=284$ *мм;* $r_к^{пер.к}=460$ *мм;* $C_1^{зад.к}=25{,}5$; $C_2^{зад.к}=17{,}7$; $D^{зад.к}=1540$ *мм;* $b_к^{зад.к}=394$ *мм;* $r_к^{зад.к}=730$ *мм;* [2,10].
The analysis of the array of wear intensity values per unit length showed that with an increase in the slope of the egat, the wear intensity for the tire 18.4 / 15-30 R-319 increases to $4•10^{-11}$ relative to the increase in air pressure from 0.08 to 0, 2 MPa.
To keep the tractor on the trajectory, it is necessary to set an admissible low value of the air pressure in the wheels of the rear axle (p_ω = 0.08 MPa) due to the fact that they are subjected to traction loads, as well as to create excessive steering of the tractor, which will allow to increase the interval of variation of the driving angle front wheels. Thus, the intensity of the wear of the rear wheels will have a constant value, and the value of the intensity of the wear of the front wheels will change due to a change in the angle of drive from 1^0 to 15^0.
An analysis of the results of mathematical experiments shows that the value of the angle of abstraction, lying within [0^0; 15^0], slightly affects the intensity of tire wear, which was another confirmation of the feasibility of the present studies. Designedbasedontheaggregateproposedbyvariousauthors [2,4]
The computational algorithm for calculating tire wear intensity during wheel rolling along an inclined (furrow) supporting surface (Figure 17) makes it possible to obtain a solution to the initial equation (14), (15) taking into account the totality of the numerical values of the desired values of wear intensity.

The program is designed to determine the intensity of tread wear per unit path length of a pneumatic wheel in cotton inclined farming conditions [2].The functions are formalized by specific formulas and intervals of allowable values that affect the wear process for the respective conditions under landscape instability and operation of the wheel propulsion.
An algorithm is used that implements the objective function of the tread wear intensity at the contact spot with the supporting (furrow) surface, which includes intervals of values such as the slope angle, tractor weight, wheel radius and width, tire pressure, tractor center of gravity, wheel track width and the functions of the normal force components for each wheel, as well as the approximation coefficients of the lateral tire retraction characteristics, the friction of rubber on the ground and the abrasive ability of the soil.
The studies are confirmed by production experiments implemented in the conditions of Kasansay district of Namangan region. This region is located in the most elevated low-mountain and high-level part of the Ferghana Valley (Uzbekistan), in connection with this, most of the fields are non-horizontalsurfaces.

Using the formula (16), we determine the tread wear depending on the tractor weight, soil load and the static radius of the tractor wheel define:

$$I=\frac{2KN\mu G\sin\alpha}{r\,b\,\pi^2\,(C_1 p\omega\, G\sin\alpha + C_2\, p_\omega G\cos\alpha)}, \quad (16)$$

I=2·0,6·80·0,3·4200·0,54/720·4700·9,86(0,6+0,5·300)=

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46656/5004936000=0,0000093 мм = 0,93 мкм

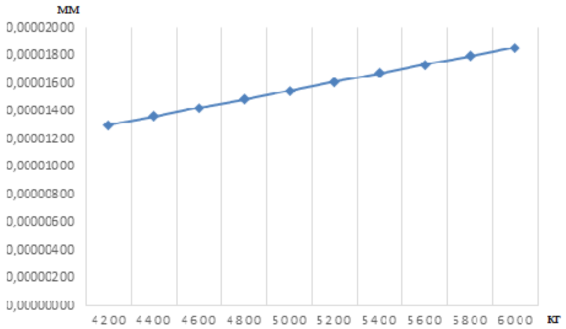

Figure 18- Dependence of tread wear on tractor weight

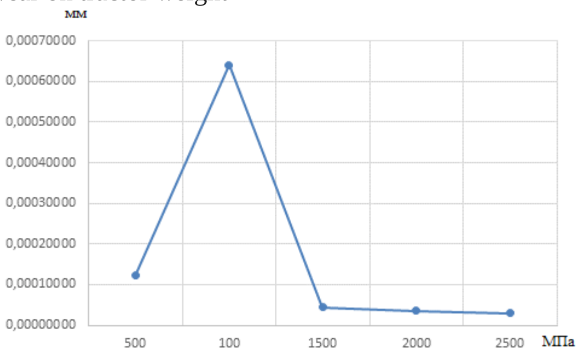

Figure 19- Dependence of wear of the tread on the load on the egate.

IV. CONCLUSION

Compared with the tire model 9.5-42 Я-183, the tire 13.6 R38 ЯR-318 by 8-9%, 15.5-38 I-166 by 11-12% and the tire 18.4/15-30 R-319 by 30-31%. When working on a tractor with a tire of model 9.5-42 Я-183 with a coupling load G_n of 1500 kg and an internal pressure of Pw = 0.18 M_n / m, the value h = 0.0754 m. Under the same conditions, with a tire 13 , 6R38 ЯR-318 h = 0.0693, and for 15.5-38 Я-166 h = 0.0676. The smallest track depth corresponds to a tire of 18.4/15-30 R-319, with an internal pressure of Pw = 0.18 Mn / m^2h '= 0.0578 m.The tire 18.4/15-30 R-319 also turned out to be significantly slightly sensitive to load changes: the difference in the amount of slipping is only 4%. It should be noted that a similar difference in slippage is observed with an increase in traction force
P = 12753 N. 18,4/15-30 R-319 by 2-3%.

An experimental study found that the tires of the middle series of the 13.6R38 ЯR-318 model have 2-3% less slippage compared to the narrow 9.5-42 Я-183 model, and the tires of the wide series are 4-5%, which allows them develop traction force, respectively, 7-8% more than wide and 13% more than narrow series tires. And the actual speed developed by medium and wide tires compared to narrow is 9-10% and 16-18% more, respectively.

It was suggested, according to the results of comparing the complex of towing and coupling and agrotechnical indicators, that in the rows of 0.6 m it is possible to use tires with a width of up to 0.305 m, in the rows of 0.9 m - tires with a width of 0.426 m. Average resources 15.5-38 Я-166 and 18.4/15-30 R-319 tractor tires, the probability of tire failure was 86%, i.e. above the specified equal to 80%.

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