Influence of removable anti-skid device on the soil density

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Abstract. The ways to improve the traction characteristics of the wheel MTA by the drive wheels loaders, the use of additional removable loads, the filling of the drive wheels chambers with liquid, the traction force of the tractor due to the increase in the coupling mass are studied. However, with the increase in the structural dimensions of the wheels and the use of dual tires improve the functional properties of the engines, however, significantly increase the cost of the engine, its dimensions, complicated handling of the machine. The use of removable anti-skid devices on the wheel drive increases the vertical load due to the weight of the anti-skid device. At the moment of interaction of the hook with the soil, the force required to introduce it into the soil, reduces the load on the wheel. A formula for determining the density of soils in the wake of the mover is obtained. Depending on the magnitude of the force of introduction into the soil, two modes of interaction of the wheel with the soil are considered. To improve the traction properties of the engine, a new design of the device support was developed. After the introduction of the support to a dense layer of soil, it is opened, thereby increasing the contact area and sharply reducing the pressure of the wheel drive tires on the upper layers of the soil. Due to this process, the wheel (partially or completely) is not in contact with the topsoil. The equipment of propellers of wheeled vehicles with removable anti-skid devices, which allow to increase traction properties, reduce the compacting effect of the propulsor on the soil, seems to be a rational solution to the problem of increasing the traction characteristics of the driving wheels. The equipment of wheel machines movers with removable anti-skid devices allows to approximate the traction characteristics of wheel machines to the characteristics of crawler type movers due to the interaction of hooks with more compacted layers of the subsurface horizon soil.

1. Introduction

Depending on the location of the left and right driving wheel lugs arise when driving slopes and distortions of transport vehicles. Coupling properties are lost and determined by the traction ability only from removable lugs models (5) and (6).

In order to reduce these negative phenomena, it is necessary to develop devices to reduce vibration and distortions of the tractor (with a variable radius of the center of the wheel) and improve traction properties (forming a support in the subsurface layers of the soil). Development work in these areas is necessary. As an example, we can show the following development (patent for invention № 2349460...
RF, IPC 60 in 15/26. A method of increasing the traction properties of the engine and the device for its implementation.

The anti-skid device performs the function of the bearing base and traction properties. The device consists of (Figure 1) from the axis 1 fixed to the wheel rim disc by nuts 2, cheek 3 fixing the position and guide bracket 4. Inside the bracket moves the rack 5, fixed lock 6 with a spring 7. At the top of the rack there is a roller 8, swinging on the surface of the Cam 9, which is mounted on a fixed axis 10. In the lower part of a rack the support is fixed (Figure 2) devices 11, the working surface of which is made in the form of a triangle, hinged on the axis 12.

The principle of operation of the device is as follows. When rolling the wheel on soft waterlogged soils, the rack 5, due to the shape of the Cam, introduces the support 12 in the closed state in the subsurface layer of the soil. When introducing the support 12, the soil pressing on its edges, opens the support of the device 11. Due to this process, the wheel (partially or completely) does not come into contact with the topsoil. The anti-skid device performs the function of the bearing base and traction properties. With further rolling of the wheel, the support 11, coming out from under the arable layer, loosens the soil and closes. In interaction with the surface of the rolling wheel enters the next device and the cycle is repeated.

Figure 1. Anti-skid device for vehicle wheel.

Figure 2. Anti-skid support.

The use of removable anti-skid devices on the wheel drive increases the vertical load due to the weight of the anti-skid device (Figure 3). However, at the moment of interaction of the hook with the soil, the force required to introduce it into the soil, reduces the load on the wheel. Therefore, at the moment, the density of the soil in the wake of the mover is defined as:
\[
\gamma_{cl} = \gamma_0 + \Delta \gamma_k + \Delta \gamma_Y - \Delta \gamma_B, \quad (1)
\]

where \(\gamma_0\) - relative density of soil, respectively, the initial (before passage) and the track mover, kg/m\(^3\); \(\Delta \gamma_k, \Delta \gamma_Y, \Delta \gamma_B\) - the increment of the density of the soil, respectively, from the wheel loads, the device weight of snow and force the introduction of the hook in the soil, kg/m\(^3\).

Expressing the density increment through the weight parameters, we obtain:
\[
\gamma_{cl} = \gamma_0 + k_G \cdot (G_k + \gamma_k \cdot \mathbf{g} - P_b), \quad (2)
\]

where \(k_G\) - the coefficient of proportionality of the increment of the density of the soil per unit load, m\(^3\), defined by the expression; \(g\) - gravitational acceleration, m/s\(^2\).

Figure 3. Effect of vertical load on soil density in the wake of the mover.

2. Results and discussion

The calculated values of the model (1) of certain intervals of variation of the studied factors (table. 2) presented in table. 1. The analysis of the influence of the studied factors on the density of the soil in the Wake of the mover, at the Central level of variation shows them (table. 1) that with increasing height of the removable lugs on the wheel, regardless of their number, it decreases along a curve with a negative acceleration. For \(Z_c = 2\) PCs., \(4\) PCs., \(6\) PCs., conl respectively increases, in the range of \(h_c\) from 0 to 0.1 m, by 1.04 %, 1.02 % and 1.01 %. With an increase in \(h_c\) from 0.1 to 0.2 m, the usl increases, depending on the number of removable lugs, respectively, by 1.05; 1.03 and 1.02 %.

With the increase in the length of the removable lugs on the wheel, regardless of their number, the density of the soil in the track of the mover is reduced by a linear dependence of 5 kg/m\(^3\). The study of the hook load in these intervals of variation of the studied factors does not have a significant impact.

With the increase in the number of removable ground hooks on the wheel, regardless of their height, with a Central level of variation of factors, the density of the soil in the Wake of the mover increases along the curve with a positive acceleration. For \(h_C = 0\) m, relative increases in the range \(Z_c\) from 2 to 4 pieces by 1.04 %, with \(h_C = 0.1\) m – 1, 05 %, for \(h_C = 0.2\) m – 1.06 %. By increasing the \(Z_c\) from 4 to 6 PCs., con increases, depending on the height of the removable lugs, respectively, 1.09; 1.10 and 1.12 %.
This increase in soil density is explained by the fact that with the increase in the number of hooks increases the load on the wheel.

With the increase in the length of removable lugs on the wheel, regardless of their height, the density of the soil in the Wake of the mover decreases proportionally. Moreover, with the increase in the height of the ground hooks, the intensity of the decrease in soil density increases, and for \( h_C = 0.1 \text{ m} \) it is 5 kg/m\(^3\), and for \( h_C = 0.2 \text{ m} \) – 10 kg/m\(^3\). In order to determine the time of interaction with the soil, as a criterion for assessing the length of the less compacted part of the soil trace, which depends mainly on the strength of the introduction of the hook into the soil, its height, the number and slipping of the wheel.

Depending on the magnitude of the force of introduction into the soil, there are two modes of interaction of the wheel with the soil.

1. The implementation force of the hook is less than the load on the hook:
   \[
   P_s \leq G_k + Z_c \cdot m_g. \tag{3}
   \]

   The density in the trace will be variable and will reach its minimum at the fully entered hook in the soil (Figure4). Therefore, taking into account the processes of slipping and the number of removable lugs on the wheel, we determine the area of the less compacted part of the track by the engine for the rotation of the wheel \( L_{cl} \):
   \[
   L_{cl} = (1-\delta_k) \cdot Z_c \cdot \sqrt{(R_k + h_c)^2 - (R_k - h_k - h_z)^2}. \tag{4}
   \]

### Table 1. Calculated values of soil density in the Wake of the mover \( \gamma_{cl} \text{ (kg/m}^3\text{)} \).

| \( Z_c \), PCs. | \( h_c \), m | \( l_c \), m | \( P_{KP} \), kN |
|----------------|------------|------------|--------------|
| 2              | 1448       | 1432       | 1418         |
| 4              | 1463       | 1448       | 1433         |
| 6              | 1479       | 1464       | 1449         |

| \( h_c \), m | \( Z_c \), PCs. | \( l_c \), m | \( P_{KP} \), kN |
|------------|----------------|------------|--------------|
| 0          | 1448           | 1463       | 1479         |
| 0.1        | 1433           | 1448       | 1464         |
| 0.2        | 1418           | 1433       | 1449         |

| \( l_c \), m | \( Z_c \), PCs. | \( h_c \), m | \( P_{KP} \), kN |
|-------------|----------------|------------|--------------|
| 2           | 1438           | 1453       | 1469         |
| 4           | 1433           | 1448       | 1464         |
| 6           | 1428           | 1443       | 1459         |

| \( P_{KP} \), kN | \( Z_c \), PCs. | \( h_c \), m | \( l_c \), m |
|-----------------|----------------|------------|--------------|
| 4               | 1433           | 1448       | 1464         | 1443         |
| 5               | 1433           | 1448       | 1464         | 1443         | 1443         |
| 6               | 1433           | 1448       | 1464         | 1443         | 1443         |
Figure 4. The plot of ground pressure wheels with claws for his one turn:
a-ZC =2 PCs, b-Zc =3 PCs, c-ZC =4 PCs, d-ZC =5 PCs, e – ZC =8 PCs.

The analysis of the influence of the studied factors on the zone of less compacted soil in the Wake of the mover shows (table. 2) that with increase in height of removable ground hooks on a wheel, irrespective of their quantity, it rises on a curve with negative acceleration at the Central level of variation of factors. With the increase in the length of the removable ground hooks on the wheel, regardless of their number, the zone of the less compacted area of the soil in the trace of the mover increases proportionally.

Table 2. Calculated values of the zones of the least compacted area of the soil in the wake of the propeller.

| ZC, Pcs | hC, m  | lC, m  | PKP, kN |
|---------|--------|--------|---------|
| 0       | 0,1    | 0,2    | 0,05    | 0,10    | 0,15    | 4  | 5  | 6  |
| 2       | 0,64   | 0,94   | 0,62    | 0,64    | 0,66    | 0,66 | 0,64 | 0,60 |
| 4       | 1,32   | 2,02   | 1,28    | 1,32    | 1,38    | 1,38 | 1,32 | 1,28 |
| 6       | 2,00   | 3,12   | 1,92    | 2,00    | 2,08    | 2,06 | 2,00 | 1,94 |
With an increase in the hook load, regardless of the number of removable lugs, the zone of less compacted soil in the Wake of the mover decreases along the curve with negative acceleration. With the increase in the number of removable ground hooks on the wheel, regardless of their height, the zone of less compacted soil in the Wake of the mover increases in proportion.

With an increase in the number of removable lugs on the wheel, regardless of the slip coefficient at the joint interaction of removable and tire lugs, the zone in the track of the engine increases along the curve with a positive acceleration at the Central level of variation of factors. For $\delta_{csh}=0.15$, $L_{cl}$ increases in the interval $Z_c$ from 2 to 4 PCs of 9.6 %, with $\delta_{csh}=0.20$ - 6.0 %, for $\delta_{csh}=0.25$ - 4.2 %. With increasing $Z_c$ from 4 to 6 PCs., $L_{cl}$ increases, depending on the strength of the introduction of the hook into the soil, respectively, 9.6; 6.0 and 6.8 %.

With an increase in the number of removable lugs on the wheel, regardless of the height of the removable lugs, the zone in the track of the mover increases along the curve with a negative acceleration at the Central level of variation of factors. For $S = 0.1 \text{ m}$, $L_{cl}$ increases in the interval $Z_c$ from 2 to 4 PCs 7.7 %, with $L_{cl} = 0.2 \text{ m} - 7.9 \text{ %}$, for $S = 0.3 \text{ m} - 6.9 \text{ %}$. By increasing the $Z_c$ from 4 to 6 PCs, $L_{cl}$ increases, depending on the height of the hook, respectively, 5.6; 6.4 and 5.9 %.

With the increase in the number of removable ground hooks on the wheel, regardless of the diameter of the wheel, the zone in the track of the engine increases in linear dependence at the Central level of

| $h_c$, m | $Z_c$, Pcs | $l_c$, m | $P_{KP}$, kN |
|---------|-----------|----------|-------------|
|         | 2        | 4        | 6          | 0.05  | 0.10  | 0.15  | 4      | 5      | 6      |
| 0       | 0        | 0        | 0          | 0     | 0     | 0     | 0      | 0      | 0      |
| 0.1     | 0.64     | 1.32     | 2.00       | 1.28  | 1.32  | 1.38  | 1.38   | 1.32   | 1.28   |
| 0.2     | 0.94     | 2.02     | 3.12       | 1.92  | 2.02  | 2.12  | 2.10   | 2.02   | 1.96   |

| $l_c$, m | $Z_c$, Pcs | $h_c$, m | $P_{KP}$, kN |
|----------|-----------|----------|-------------|
|          | 2        | 4        | 6          | 0.05  | 0.10  | 0.15  | 4      | 5      | 6      |
| 0.05     | 0.62     | 1.28     | 1.92       | 0     | 1.28  | 1.92  | 1.32   | 1.28   | 1.22   |
| 0.10     | 0.64     | 1.32     | 2.00       | 0     | 1.32  | 2.02  | 1.38   | 1.32   | 1.28   |
| 0.15     | 0.66     | 1.38     | 2.08       | 0     | 1.38  | 2.12  | 1.42   | 1.38   | 1.32   |

| $P_{KP}$, kN | $Z_c$, Pcs | $h_c$, m | $l_c$, m |
|--------------|------------|----------|----------|
|              | 2          | 4        | 6        | 0.05  | 0.10  | 0.15  | 4      | 5      | 6      |
| 4           | 0.66       | 1.38     | 2.06     | 0     | 1.38  | 2.10  | 1.32   | 1.38   | 1.42   |
| 5           | 0.64       | 1.32     | 2.00     | 0     | 1.32  | 2.02  | 1.28   | 1.32   | 1.38   |
| 6           | 0.60       | 1.28     | 1.94     | 0     | 1.28  | 1.96  | 1.22   | 1.28   | 1.32   |

With an increase in the hook load, regardless of the number of removable lugs, the zone of less compacted soil in the Wake of the mover decreases along the curve with negative acceleration. With the increase in the number of removable ground hooks on the wheel, regardless of their height, the zone of less compacted soil in the Wake of the mover increases in proportion.

With an increase in the number of removable lugs on the wheel, regardless of the slip coefficient at the joint interaction of removable and tire lugs, the zone in the track of the engine increases along the curve with a positive acceleration at the Central level of variation of factors. For $\delta_{csh}=0.15$, $L_{cl}$ increases in the interval $Z_c$ from 2 to 4 PCs of 9.6 %, with $\delta_{csh}=0.20$ - 6.0 %, for $\delta_{csh}=0.25$ - 4.2 %. With increasing $Z_c$ from 4 to 6 PCs., $L_{cl}$ increases, depending on the strength of the introduction of the hook into the soil, respectively, 9.6; 6.0 and 6.8 %.

With an increase in the number of removable lugs on the wheel, regardless of the height of the removable lugs, the zone in the track of the mover increases along the curve with a negative acceleration at the Central level of variation of factors. For $S = 0.1 \text{ m}$, $L_{cl}$ increases in the interval $Z_c$ from 2 to 4 PCs 7.7 %, with $L_{cl} = 0.2 \text{ m} - 7.9 \text{ %}$, for $S = 0.3 \text{ m} - 6.9 \text{ %}$. By increasing the $Z_c$ from 4 to 6 PCs, $L_{cl}$ increases, depending on the height of the hook, respectively, 5.6; 6.4 and 5.9 %.

With the increase in the number of removable ground hooks on the wheel, regardless of the diameter of the wheel, the zone in the track of the engine increases in linear dependence at the Central level of variation of factors. For $S = 0.1 \text{ m}$, $L_{cl}$ increases in the interval $Z_c$ from 2 to 4 PCs 7.7 %, with $L_{cl} = 0.2 \text{ m} - 7.9 \text{ %}$, for $S = 0.3 \text{ m} - 6.9 \text{ %}$. By increasing the $Z_c$ from 4 to 6 PCs, $L_{cl}$ increases, depending on the height of the hook, respectively, 5.6; 6.4 and 5.9 %.

With the increase in the number of removable ground hooks on the wheel, regardless of the diameter of the wheel, the zone in the track of the engine increases in linear dependence at the Central level of variation of factors. For $S = 0.1 \text{ m}$, $L_{cl}$ increases in the interval $Z_c$ from 2 to 4 PCs 7.7 %, with $L_{cl} = 0.2 \text{ m} - 7.9 \text{ %}$, for $S = 0.3 \text{ m} - 6.9 \text{ %}$. By increasing the $Z_c$ from 4 to 6 PCs, $L_{cl}$ increases, depending on the height of the hook, respectively, 5.6; 6.4 and 5.9 %.
variation of factors. For \( D_k = 0.5 \, \text{m}, \) \( L_{cl} \) increases in the range of \( Z_c \) from 2 to 4 PCs. by 10.6\%, with \( D_k=1.0 \, \text{m-by 7.9}\% \), for \( D_k = 1.5 \, \text{m} \) – by 5.0\%. With increasing \( Z_c \) from 4 to 6 PCs., \( L_{cl} \) increases, depending on the diameter of the wheel, respectively, 8.2; 6.4 and 5.0\%.

The main factors affecting the density in the track of the engine are the parameters of the wheels. For the purpose of effective choice of a set of tires parameters of optimization of a wheel on energy criterion and resistance to movement of a wheel with removable hooks shall be considered.

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