The load allocation along the loader axles depending on operating conditions

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Abstract. The article presents a kinematic analysis of a front bucket loader with a center pivot frame articulation. Due to the action of external loads, the values of reactions occurring on loader motor and loading axles are determined. The article contains the results of theoretical and experimental researches of the load allocation along the tractor axles on the basis of the cargo mass and the hoisting height. The dependencies of the force allocation along the loader axles are obtained according to the operating conditions.

Loaders, as an integrated part of any technological loading process, must work effectively with any type of cargo, regardless of its physical and mechanical properties. A specific group of machines includes front-mounted single-bucket rubber-tired loaders with a center pivot frame articulation. When conducting kinematic studies of the loading process, it is possible to achieve an increase of the technical and operational indicators [1].

For the loader with 4 x 4-wheel arrangement, which has a blocked drive, the mass allocation along the axles affects significantly the operating process. Let us consider the load allocation along the loader axles on the basis of the operating conditions [1, 2]. On a standstill position, the following normal reactions are acted upon the loader wheels from the soil:

- $R_1$ – normal reaction of the motor axle, N;
- $R_2$ – normal reaction of the loading axle, N.

Reactions occur when subjected to external loads, N:

- $F_T = m_T g$ - from the base machine;
- $F_C = m_C g$ – from the mass of a lifting arm;
- $F_K = m_K g$ – from the mass of a bucket;
- $F_G = m_G g$ – from the mass of cargo.

The reactions are determined according to the kinematic model (figure 1) from the equation of the sum of force moments with regard to points 1 and 2.

\[
\begin{align*}
\sum M_1 &= g[m_T L_T + m_C (L - L_C) + (m_K + m_T)(L + L_{KG})] - R_2 L = 0 \quad (1) \\
R_2 &= g[m_T L_T + m_C (L - L_C) + (m_K + m_T)(L + L_{KG})]/L. \quad (2) \\
\sum M_2 &= g[-m_T(L - L_T) - m_C L_C + (m_K + m_T)L_{KG} + R_1 L] = 0 \quad (3) \\
R_1 &= g[m_T(L - L_T) + m_C L_C - (m_K + m_T)L_{KG}]/L. \quad (4)
\end{align*}
\]
Thus, when we know the coordinates of the gravity centers and the variable of forces acting on the loader, we can determine the reactions that occur on its motor and loading axles [3, 4].

![Design model for the determination of reactions on the loader axles](image1)

**Figure 1.** Design model for the determination of reactions on the loader axles.

The positions of the gravity centers of the lifting arm and the bucket with the cargo will change due to the hoisting height of the bucket. The bucket length $L_{kB}$ as (figure 1) as well as the mass of cargo in the bucket will have a significant impact on the load allocation on the tractor axles.

The variable of the bucket length, in its turn, depends on its hoisting height (figure 2).

$$h = h_1 - L_B \cdot \cos \alpha;$$  \hspace{1cm} (5)

$$L_{KG} = L_B \cdot \sin \alpha - L_C.$$  \hspace{1cm} (6)

![Model for the determination of the length of the loader lifting arm](image2)

**Figure 2.** Model for the determination of the length of the loader lifting arm.

On rearranging expression (2) and expression (4), it was determined the mass, applied to the motor
\(m_1\) and loading \(m_2\) axles of a loader respectively:

\[
m_1 = \frac{m_T L_T + m_C (L - L_C) + (m_K + m_G) (L + L_G)}{L},
\]

(7)

where \(m_T\) — the mass of a tractor, kg;
\(m_C\) — the mass of a lifting arm, kg;
\(m_K\) — the mass of a bucket, kg;
\(m_G\) — the mass of cargo, kg.

\[
m_2 = \frac{m_T (L - L_T) + m_C L_C - (m_K + m_G) L_G}{L}.
\]

(8)

Solving the combination of expressions (6), (7), (8) on the basis of the values of forces, acting on the loader, as well as the coordinates of their application points, the data were obtained, which are presented in table 1 and table 2 [3, 5, 6].

The analysis of the obtained data allows to draw a graph of the allocation of masses along the loader axles (figure 3, figure 4) and get the laws of their change (expression 9 — expression 14).

**Table 1.** The loading axle mass of the loader depending on the hoisting height of cargo (when the cargo mass in the bucket is different).

| The hoisting height of cargo, m | The loading axle mass of the loader, kg | The cargo mass in the bucket, kg |
|---------------------------------|--------------------------------------|---------------------------------|
| 1                               | 7420                                 | 10200                           |
| 2                               | 7680                                 | 10710                           |
| 3                               | 7700                                 | 10840                           |
| 4                               | 7540                                 | 10600                           |
| 5                               | 6190                                 | 9990                            |

**Table 2.** The motor axle mass of the loader depending on the hoisting height of cargo (when the cargo mass in the bucket is different).

| The hoisting height of cargo, m | The motor axle mass of the loader, kg | The cargo mass in the bucket, kg |
|---------------------------------|--------------------------------------|---------------------------------|
| 1                               | 6930                                 | 5870                            |
| 2                               | 6710                                 | 5350                            |
| 3                               | 6700                                 | 5300                            |
| 4                               | 6870                                 | 5700                            |
| 5                               | 7240                                 | 6540                            |

The obtained dependencies lead to the conclusion that if the cargo mass in the bucket \(m_G\) increases, there occurs the allocation of masses, with their increase on the loading axle of the loader and their decrease on the motor axle of the loader. When the hoisting height is \(h = 2.7\) meters, the load on the loading axle has the maximum value, and the load on the motor axle is minimal [7, 8]. This is explained by the change in the length of the loader bucket outreach (expression 6), the variable of which has a maximum value when \(\alpha = 90^\circ\) and \(h = 2.7\) m.

The equation of load allocation along the axles when there is no cargo in the bucket, kg:

on the motor axle:

\[
m_1 = 102h^2 - 535.2h + 7376.6;
\]

(9)

on the loading axle:

\[
m_2 = -92.9h^2 + 497.7h + 7022.3.
\]

(10)

The equation of load allocation along the axles when the cargo mass in the bucket is 2000 kg:
on the motor axle:

\[ m_1 = 232.5h^2 - 1224.3h + 6861.9; \] (11)

on the loading axle:

\[ m_2 = -193.6h^2 + 1103.1h + 9274.9. \] (12)

The equation of load allocation along the axles when the cargo mass in the bucket is 4000 kg:

on the motor axle:

\[ m_1 = 356.9h^2 - 1952.2h + 6342.1; \] (13)

on the loading axle:

\[ m_2 = -320.2h^2 + 1802.5h + 11868.1. \] (14)

**Figure 3.** Load allocation on the loading axle of the loader depending on the hoisting height of the lifting arm to the cargo mass in the bucket, kg: line «1» - 0; line «2» - 2000; line «3» - 4000.

**Figure 4.** Load allocation on the motor axle of the loader depending on the hoisting height of the lifting arm to the cargo mass in the bucket, kg: line «1» - 0; line «2» - 2000; line «3» - 4000.

**References**

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