INCREASING THE EFFICIENCY OF TRANSPORTATION OF CARGOES WITH A CYLINDRICAL SHAPE

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Resume

One of the most important directions of intensification and increasing the efficiency of the transportation process is to improve the use of the carrying capacity and capacity of vehicles. For this, it is necessary to the choose rational schemes for loading the cargo into cargo places of the rolling stock. The possible options for loading the vehicle body with cylindrical loads, which are transported when they are installed on the end, are considered. The conducted analysis showed that there are several typical schemes for loading such cargoes. Analytical dependencies have been obtained that allow choosing a rational loading scheme when transporting such cylindrical loads, considering their parameters and the characteristics of cargo places of vehicles. Based on the performed research, the best variant is proposed, i.e. the option with the clearance of 0.2 m, allowing transportation of 125 cylindrical cargo units in the space of a vehicle.

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1 Introduction

The situation on the logistics markets is becoming more complicated today due to the increase in transport costs due to the increase in fuel prices, transport tariffs, etc. The carrier cannot influence the monopolies' tariffs, while by increasing the percentage of his profit in the price of transportation, he risks losing customers. There is only one way left - to improve transportation planning and increase the work efficiency. Improving the use of the carrying capacity and capacity of vehicles is one of the most important areas of intensification and increasing the efficiency of the transportation process [1-4].

Faster and more efficient transportation of goods from the consignor to the consignee can be facilitated by use of the modern transport technologies and promising energy-efficient technical solutions [5-8]. Ensuring the safety of the transport process is no less important [9-12].

A common type of cargo transported by any mode of transport is cargo that has the shape of a cylinder (hereinafter - CCS). Such loads can be divided into several groups based on their weight and overall characteristics. The first group includes various pipes and containers. The ratio of the height of the cylinder to its diameter is high enough for such cargoes. Those cargoes are placed in the vehicle body in such a way that the generatrixes of cylinders are parallel to the longitudinal axis of the vehicle body. Schemes of loading such cargoes into vehicle bodies depend on the weight and overall characteristics of these cargoes and are usually developed by manufacturers. The other group includes loads in which the ratio of the height of the cylinder to its diameter is no more than 2 m to 3 m. These are both packaged and unpackaged goods: wooden and metal barrels, tanks, drums, rolls, coils, bays, and so on. Most often, such cargoes are transported by installing them on the base of the cylinder.

To increase the efficiency of transportation of such cargoes, it is necessary to rationally use the carrying capacity and capacity of vehicle bodies due to the optimization of cargo loading schemes. This can sometimes be quite a difficult task due to the specifics of the mass-dimensional characteristics of individual cargo packages.

When planning the loading of such cargoes into the body of vehicles, it is necessary to ensure the maximum use of their carrying capacity and floor area of the body. At the same time, it is necessary to take into account the basic conditions and requirements for their placement and fastening, which are defined in [13-15] and the corresponding rules of cargo transportation.

In our opinion, insufficient attention is paid to this topic. Those studies are quite few. For example, work [16] is devoted to the problem of improving the use of heavy-duty road trains by increasing their actual load. The task of optimization of loading schemes was solved in three stages. An example of solving the optimization problem of the cargo units placement in a five-axle road train is formulated and shown. In article [17], based on dynamic programming, recommendations were developed for selecting the optimal vehicle loading plan.

The use of information technologies in development of the load placement and fastening schemes significantly reduces development time, increases the productivity of scheme developers, who have the opportunity to concentrate their attention on more complex stages of calculation that are not amenable to automation. It is inefficient to determine the loading scheme experimentally. So, for example, in work [18] it is proposed to use a genetic algorithm for this - a search heuristic algorithm used to solve optimization tasks in the field of computer science and artificial intelligence.

However, in some cases, it is advisable to use the simpler means to choose a rational scheme for loading cargo into the body of optimize the scheme of loading cargo into the body, taking into account their mass and dimensions parameters and the characteristics of cargo places of rolling stock [19-20].

The purpose of this article was to determine analytical dependencies that allow choosing a rational loading scheme for the transportation of cylindrical loads, taking into account their parameters and the characteristics of cargo places of vehicles [21-25].

2 Research methodology

Analysis of possible options for loading vehicle bodies with cylindrical loads, when installing them on the end, shows that there are several typical loading schemes (Figure 1). These schemes are also depicted in 3D views (Figure 2).

For the most effective use of the vehicle's capabilities, when solving the problem of determining the maximum number of cylindrical cargo that can be placed in the body, depending on its characteristics and overall dimensions of one CCS cargo package, the following calculation dependencies were obtained for the considered loading schemes:

- for the loading scheme (Figure 1, *a*):

$$G_a = N_a \cdot M_a = \left[\frac{H}{h}\right] \cdot \left[\frac{B}{2R}\right] \cdot \left[\frac{L}{2R}\right], \tag{1}$$

- for the loading scheme (Figure 2, *b*):

$$G_b = N_b \cdot M_b = \left[\frac{H}{h}\right] \times \left[\frac{B}{2 \cdot R + Z \cdot \left[\left(\frac{B}{2 \cdot R} - 1\right)\right]}\right] \cdot \left[\frac{L}{2 \cdot R - S}\right], \tag{2}$$

- for scheme (Figure 1, *c*) with an even total number of rows of cargo in the longitudinal direction:

$$G_{c1} = N_{c1}^{p} \cdot M_{c1}^{p} + N_{c1}^{np} \cdot M_{c1}^{np} = \left[\frac{H}{h}\right] \times \left\{\left(\frac{B}{2 \cdot R + Z \cdot \left(\frac{B}{2 \cdot R}\right) - 1}\right) \cdot \frac{\left(\frac{L}{2 \cdot R - S}\right)}{2} + \left[\left(\frac{B}{2 \cdot R + Z \cdot \left(\frac{B}{2 \cdot R}\right) - 1}\right) - 1\right] \cdot \frac{\left(\frac{L}{2 \cdot R - S}\right)}{2}\right\}, \tag{3}$$

- for scheme (Figure 1, *c*) with an odd total number of cargo rows in the longitudinal direction:

$$G_{c2} = N_{c2}^{p} \cdot M_{c2}^{p} + N_{c2}^{np} \cdot M_{c2}^{np} = \left[\frac{H}{h}\right] \times \left\{\left(\frac{B}{2 \cdot R + Z \cdot \left(\frac{B}{2 \cdot R}\right) - 1}\right) \cdot \left(\frac{\left(\frac{L}{2 \cdot R - S}\right)}{2} + 1\right) + \left[\left(\frac{B}{2 \cdot R + Z \cdot \left(\frac{B}{2 \cdot R}\right) - 1}\right) - 1\right] \cdot \frac{\left(\frac{L}{2 \cdot R - S}\right)}{2}\right\}, \tag{4}$$

where N_i is the number of cargo units placed in one row along the width of the body with the selected loading scheme,
M_i - the number of transverse rows of cargo stacking in the body with the selected loading scheme;
H, B, L - height, width and length of the vehicle body, respectively;
$2R$ - diameter of one cargo place;
h - height of one cargo place;
S - the depth of the "saddle", which is formed by two adjacent CCS cargo places when installing the second and subsequent rows of cargo in the body (Figure 2 for loading schemes (*b*) and (*c*)).

Rounded down values of the corresponding expressions are indicated by square brackets, [...].

The value of S, in the general case, depends on the diameter $D = 2 \cdot R$ of one cargo place of a cylindrical cargo and the size of the existing places Z between the cargo places in a row (Figure 3).

The analysis of geometric ratios, according to Figure 2, allows us to determine [25] that

$$S = 2R - \sqrt{4R^2 - (R + Z/2)^2}\,. \tag{5}$$

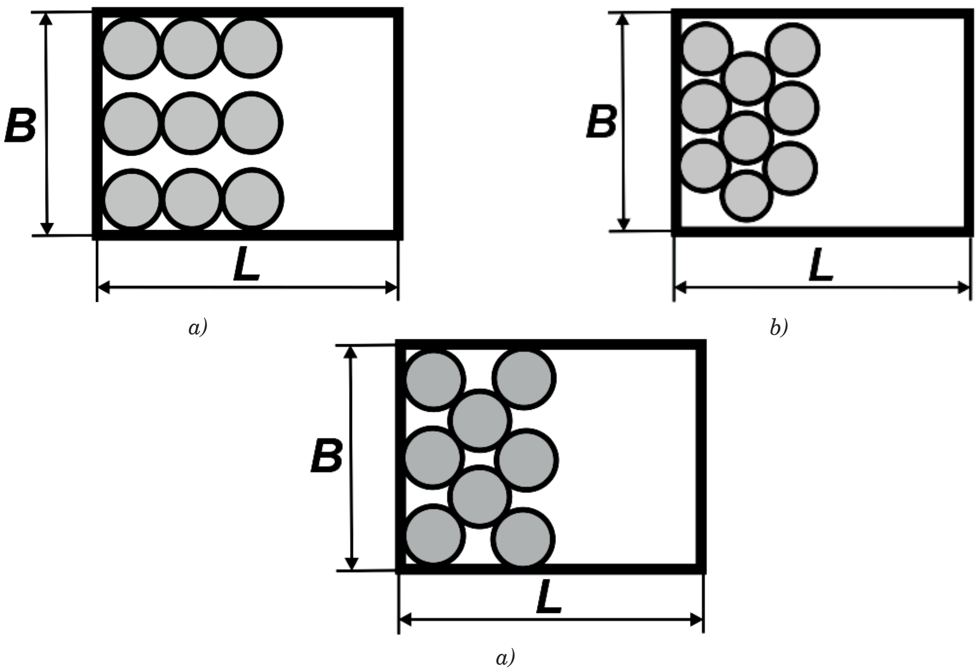

Figure 1 *Variants of CCS loading schemes in the body – 2D views*

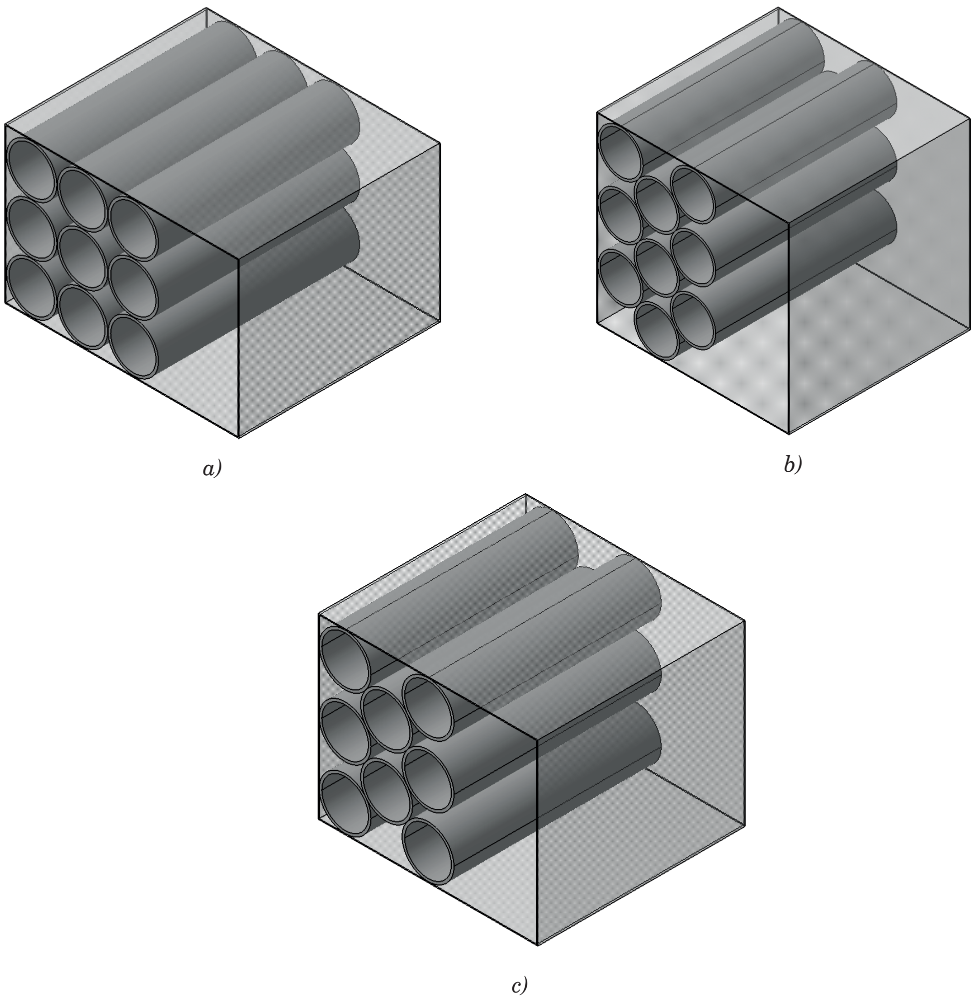

Figure 2 *Variants of CCS loading schemes in the body – 3D views*

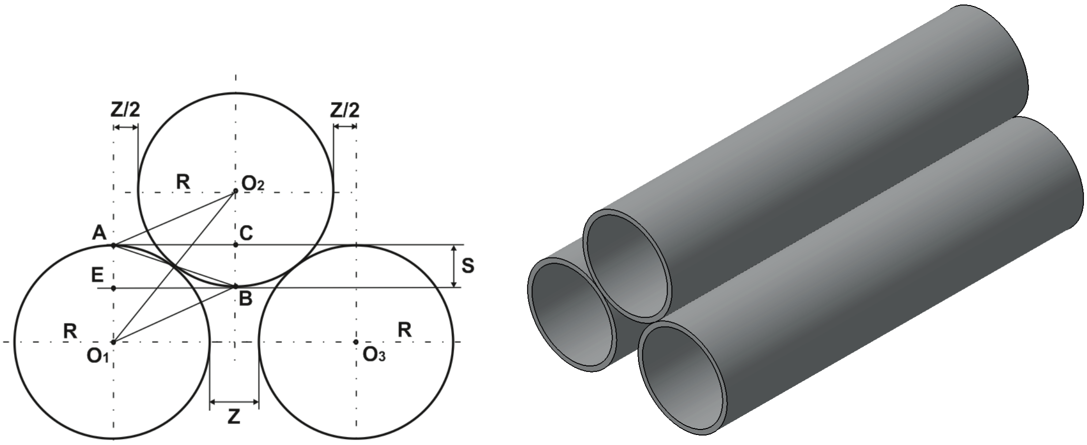

Figure 3 *A calculation scheme*

It should also be remembered that the scheme of placement and fastening of cargo, in different cargo transport units, depends on the type of cargo and the design of the body. For example, the strength of the side walls and the front and rear of the body is important for cars [13].

3 Results and discussion

A large number of different modifications of semi-trailers are used for cargo transportation by vans, among which one can distinguish both small semi-trailers with a volume of 75 to 80 m^3 (with a body length of 12 to 13 m), and standard semi-trailers with a body volume of 82 to 96 m^3. They have a body length of 13.6 to 15 m, a width of 2.4 to 2.5 m and a height of 2.5 to 2.7 m.

Some calculation results are given in Figures 4 and 5, as examples illustrating the dependencies $G_i = f(R, Z)$ for loading schemes *a* and *b* (Figure 1) and for loading scheme *a* and *c*2, respectively, when loading a cargo space, which has the geometric parameters of the cargo space of a semi-trailer with a width of 2.4 m and a length of 13.6 m. The quantity G_i is the total number of cylindrical cargoes that fit in the cargo space of the vehicle and it is unitless quantity. The scale 0 to 400 of the G_i is a scale for determining the total number of cylindrical cargoes, which are placed in the cargo space of a vehicle when using various loading schemes for the initial data adopted in the considered calculation example.

The height of one CCS cargo place is assumed equal to h = 1 m, loading is carried out in one tier.

The proposed analytical dependencies make it

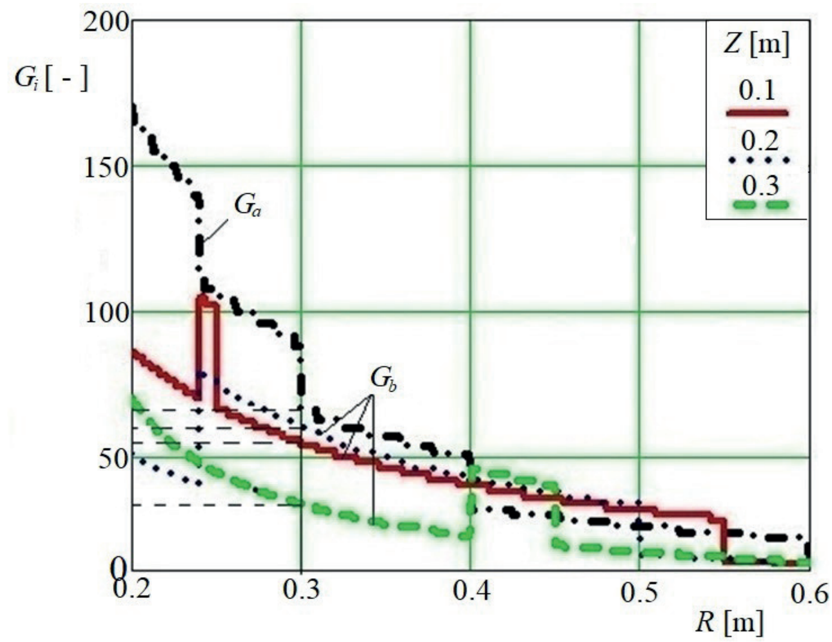

Figure 4 *An example of dependence $G_i = f(R, Z)$ for the loading schemes (a) and (b)*

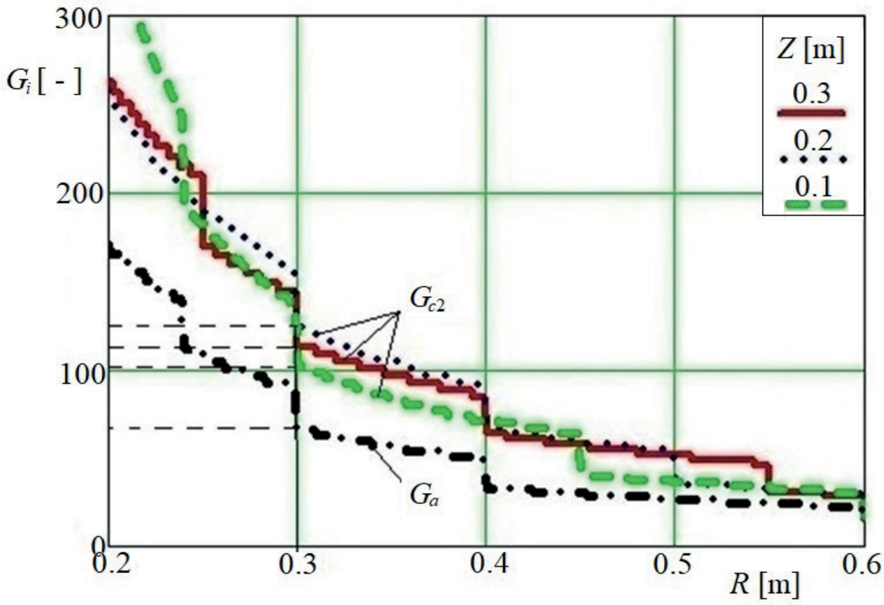

Figure 5 *An example of dependence $G_i = f(R, Z)$ for the loading schemes (a) and (c2)*

possible to substantiate the choice of the optimal loading scheme given the known parameters of the vehicle body and the given mass-dimensional indicators of cylindrical cargoes.

At the same time, it should be considered that the ratio must be fulfilled:

$$G_i \cdot q \leq Q_{\max}, \tag{6}$$

where q is the mass of one cargo place,
Q_{max} - carrying capacity of the vehicle.

Determining the most efficient schemes for loading the cylindrical cargo based on the proposed analytical design dependencies makes it possible to more rationally use the cargo capacity of the cargo space of a vehicle. The use of the carrying capacity of the vehicle in this case will depend on the weight q of one unit of cylindrical cargo, considering the maximum carrying capacity of the euro truck (in our case, up to 24 tons). This mass depends on properties of the cylindrical cargo itself and can vary widely.

4 Conclusions

Improving the use of the carrying capacity and capacity of vehicles is one of the most important directions of intensification and increasing the efficiency of the transportation process.

A common type of cargo transported by any mode of transport is cargo that has the shape of a cylinder. Those are both packaged and unpackaged goods: wooden and metal barrels, tanks, drums, rolls, coils, bays, and so on. Most often, such cargoes are transported by installing them on the end.

The analysis of possible options for loading the vehicle body with cylindrical cargoes when they are installed on the end showed that there are several typical schemes for loading such cargoes. Analytical dependencies have been obtained that allow choosing a rational loading scheme when transporting such cylindrical cargoes, taking into account their parameters and the characteristics of cargo spaces of vehicles.

For the initial data adopted in the calculation example, it was obtained that when loading cylindrical goods with a radius of 0.3 m into the cargo space of an automobile semi-trailer with a width of 2.4 m and a length of 13.6 m. when using the loading scheme (*a*), can be placed approximately 70 cargo units, while the use of the best variant of the loading scheme (*b*) with a clearance of Z = 0.2 m allows only 62 cargo units to be placed in the same space. For the initial data taken in the calculation, the best option would be to use the C_2 loading scheme (Figure 4), which, with a value of transverse clearances Z = 0.2 m between the packages, allows 125 cylindrical cargo units to be placed in the cargo space of vehicle.

Thus, determination of the most efficient schemes for loading the cylindrical cargo based on the proposed analytical design dependencies makes it possible to use the cargo capacity of the cargo space of a vehicle more rationally. The completeness of the use of the carrying capacity of the vehicle, in this case, depends on the mass of one unit of cylindrical cargo, considering the maximum carrying capacity of a vehicle.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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