

LOCATION OF PALETISED UNITS ON RAILWAY WAGON

ROZMIESZCZENIE JEDNOSTEK PALETOWYCH NA WAGONIE KOLEJOWYM

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Abstract: *In this research the example of palletised units location on railway wagon has been shown. Based on the dimensions provided in the wagons catalogue, the maximum amount of units has been proposed and parameters of load were determined for the conditions of such placement. The obtained results were compared with the guidelines published by PKP CARGO and UIC.*

Streszczenie: *W artykule został przedstawiony projekt rozmieszczenia jednostek paletowych na wagonie kolejowym. Na podstawie wymiarów wagonu kolejowego została dobrana maksymalna ilość jednostek paletowych, które mogą być rozmieszczone oraz zostały obliczone parametry wynikające z takiego wariantu rozmieszczenia. Na końcu wyniki zostały zestawione z wymaganiami, jakie są stawiane przez PKP CARGO S.A. oraz Międzynarodowy Związek Kolei (UIC).*

Keywords: *rail, palletised units, railway wagon, loading guidelines, location of goods.*

Słowa kluczowe: *transport kolejowy, rozmieszczenie ładunków, jednostki paletowe, wagon kolejowy.*

Introduction

Railway transport is one of the oldest type of transportation. Every day all kind of goods are transported by the railways tracks. This includes the general cargo – mostly exposed to damages and oversized heavy load, which should be moved according to the special terms.

Location of goods in a railway car is one of the most significant element of the loading process. Requirements for the load distribution are provided in the operators guidelines or UIC (International Union of Railways) loading regulations if is the cargo transported by international tracks. The most significant issue regarding the cargo location is to prevent the overload of one of the axle or bogie. Maximum allowed cargo load depends on the rail line category, described in the UIC regulations. The load should be also distributed as evenly as possible without exceeding the maximum axle or bogie ratio.

Inappropriate loading process may cause the damage of the railway car or transported goods. Wrong cargo distribution can be a result of not-fully qualified employees regarding the regulations or the loading guidelines. The most common errors during goods transport are caused by using wrong type of securing and oversized the loading gauge.

The aim of this article is to propose palletised unit distribution for selected wagon car, and to analyse the parameters which are results of this project. The literature analysis as well as regulations review enabled to define the essential factors affecting the cargo distribution in railway transportation. Then, the factors were used to establish the palletised units on Habbils – series wagon car.

1. Regulations for cargo distribution

Requirements for cargo distribution are presented in two primary statues:

- Polish State Railway (PKP S.A.), regulation about loading and securing goods,
- UIC loading guidelines, section 1 (principles) and 2 (goods).

Those documents indicate that palletised units should be distributed on wagon car:

- to not to overweight the maximum load per axle (table 1)
- as evenly as possible to not to exceed maximum ratio, which is:
 - per axle, $\max\left(\frac{Z_1}{Z_2}, \frac{Z_2}{Z_1}\right) < \frac{2}{1}$ (1)
 - if wagon is equipped in bogies, $\max\left(\frac{Z_1}{Z_2}, \frac{Z_2}{Z_1}\right) < \frac{3}{1}$ (2)
- in a way that transported goods are not protrude of the loading gauge.

Table 1. Maximum load per one axle depends of line category

Line category	Maximum load [kN]
A	160
B_1, B_2	180
C_2, C_3, C_4	200
D_2, D_3, D_4	225

Source: own work, based on: *Loading Guidelines*, Section 1: Principles, UIC

Next factor which influences the transport safety is choice of the appropriate securing method to rigid the load formation. Maximum values of stresses during transport, which are not cause damages are as follows:

- lengthways in the wagon – 4 g;
- crosswise in the wagon – 0,4 g;
- vertically in the wagon – 0,3 g;

where g – gravitational acceleration

Most appropriate way to stabilize the palletised units is to move all load, maximum up to the front or side wall using fastening, paper airbags, empty pallets and other wooden or steel construction.

2. Wagon characteristics

Habills series wagon is equipped in moveable walls which are weatherproof and provide access to whole wagon from the loading ramp. On figure 1 the scheme of wagon was presented and basic wagon dimensions were shown in table 2.

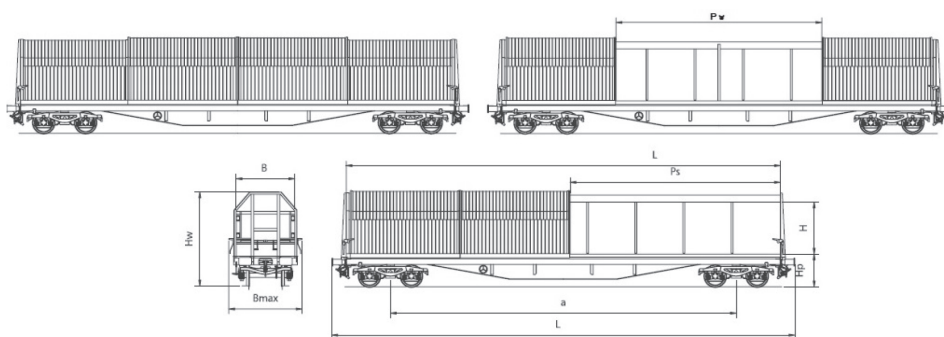


Fig. 1. Scheme of wagon Habills series

Source: *Wagon Catalogue*, PKP CARGO 2013

On figure 2 the maximum load masses (in tons) were shown, depending of the line category and wagon speed. First column contain speed, for example S –

100 km/h, 0,00 – indicates that at this speed wagon can be moved only when it is empty. This table is provided by wagon manufacturer and it can be painted on the side walls or on the frame.

According to the equilibrium of forces along with wagon dimensions, it is possible to plot a graph which shows maximum load mass depending on location of goods in loading space. On the figure 3 the maximum load weight depending of good location was shown for discussed wagon for different line category.

	A	B	C
S	34,0	42,0	50,0
120	00,0		

Fig. 2. Maximum load weight in tones
Source: *Wagon Catalogue*, PKP CARGO 2013

Table 2. Dimensions of wagon

Selected Parameters of Habills – series wagon	
Track width [mm]	1435
Wagon length L_{zd} [mm]	19900
Wheelbase a [mm]	14860
Wagon width B_{max} [mm]	3030
Wagon mass m_w [kg]	30000
Wagon height measured from top of the track H_w [mm]	4100
Floor height measured from top of the track H_p [mm]	1338
Loading length L [mm]	18648
Loading width B [mm]	2434
Loading height H [mm]	1900
Maximum loading clearance P_s [mm]	8226
Middle loading clearance P_w [mm]	8854
Loading volume [m ²]	40,4
Maximum speed [km/h]	120

Source: *Wagon Catalogue*, PKP CARGO 2013

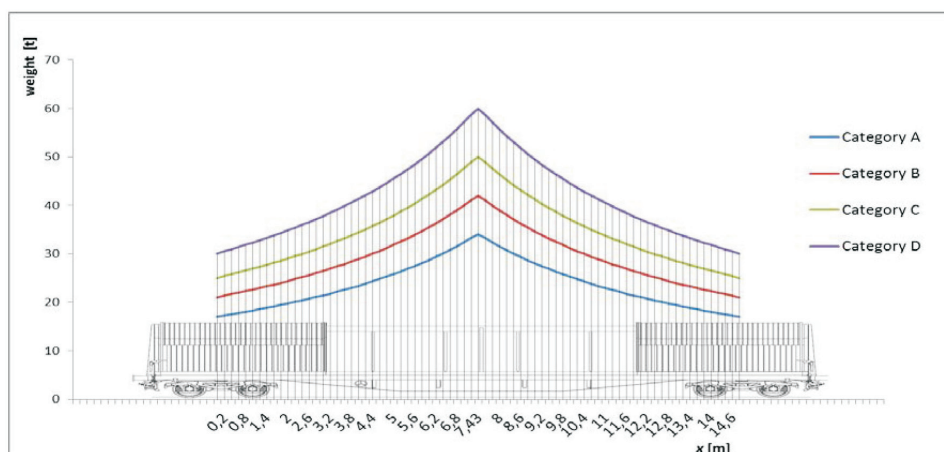


Fig. 3. Maximum load weight depending of good location

Source: own work

3. Distribution of palletised units on wagon

Carton boxes with goods are placed on EUR – standardised pallets (dimensions of pallet 1200×800 mm). Boxes are not protruding of the pallet area and were stiffed on the corners by rods. To make unit rigid, special plastic foil were used to cover goods in external layer. The total height of palletised unit is 1100 mm.

Units can be moved from ramp by forklift through the middle loading space, as it was shown in figure 1 (P_w parameter). To improve loading process special steel plates can be used to fill the gap between the ramp and wagon. On figure 4 proposition of load distribution was shown. Numbers of units match to the sequence of loading. Proposed sequence provides maximum space of loading in the most of the time and evenly distributes the load in relation to centre line.

After the load is placed in a car, in the middle of the wagon gap with 248 mm width is created. Gap can be filled by two empty pallets placed upright and paper airbags, which fully immobilises the load.

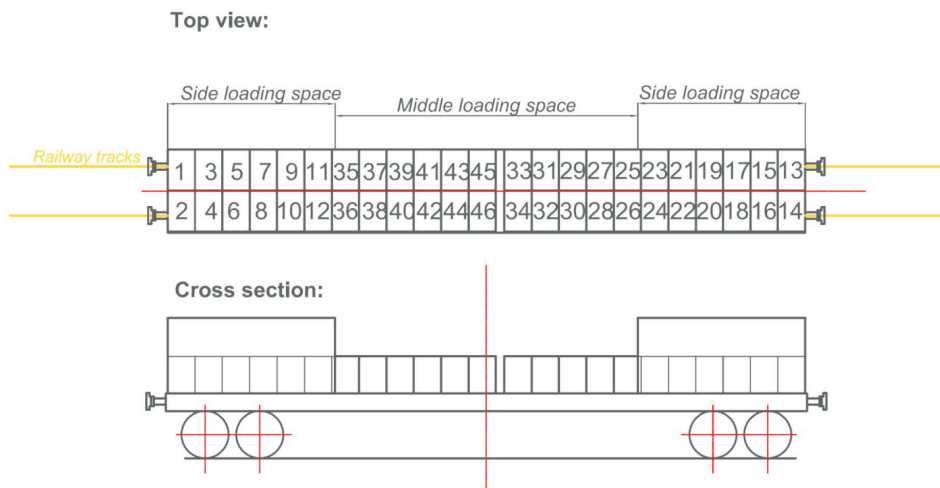


Fig. 4. Distribution of palletised units
Source: own work

4. Loading parameters calculation

The cargo in the wagon is shown as two cuboids with lengths as follows: $a_1 = 8800$ mm and $a_2 = 9600$ mm, with centres of masses in half distance of those lengths. On the figure 5 the scheme presenting the forces acting within the car was shown.

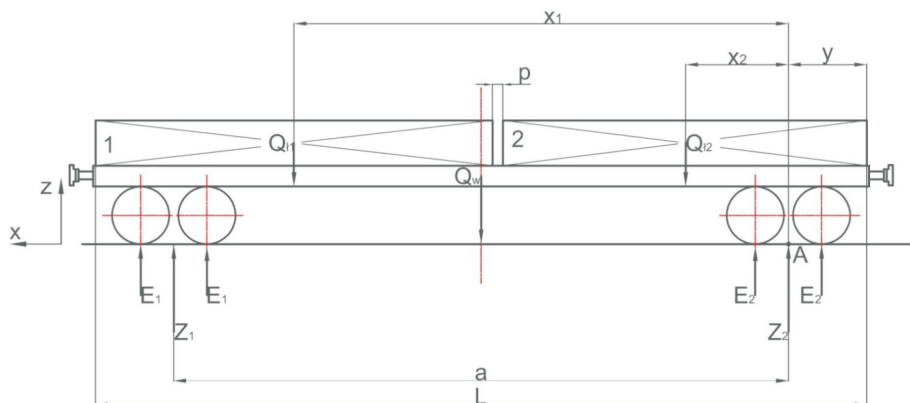


Fig. 5. Forces acting within wagon
Source: own work

where:

Q_{11}, Q_{12} – forces acting on surface by loads [kN];

Q_w – force acting on tracks by empty wagon [kN];

Z_1, Z_2 – ground reactions exerting on bogies [kN];

E_1, E_2 – ground reactions exerting on axles [kN],

a – wheelbase [mm];

L – loading length [mm];

x_1, x_2 – distance from centre of mass to bogie centre [mm];

m_{11}, m_{12} – load masses [kg];

m_w – empty wagon mass [kg];

y – distance from the bogie centre to the end of loading space [mm];

p – gap between the load $p = 248$ mm;

a_1, a_2 – load length [mm];

g – gravitational acceleration.

Calculation of y, x_1 and x_2 distance:

$$y = \frac{L - a}{2} \quad (3)$$

$$x_1 = \frac{a_1}{2} - y \quad (4)$$

$$x_2 = x_1 + \frac{a_1}{2} + p + \frac{a_2}{2} \quad (5)$$

According to the wagon series and load size, distance x_1 and x_2 were determined as follows: $x_1 = 2506$ mm and $x_2 = 11\,954$ mm. Y value, which represents the distance from the bogie centre to the end of loading space was determined as 1894 mm.

Weights of loads and empty wagon:

$$Q = m \cdot g \quad (6)$$

$$m_1 = 24 \cdot 500 \text{ kg} = 12000 \text{ kg}$$

$$m_2 = 22 \cdot 500 \text{ kg} = 11000 \text{ kg}$$

Forces acting on surfaces by the loads and wagon were calculated according to the formula 6. Those parameters are as follows:

$$Q_{11} = 120 \text{ kN}$$

$$Q_{12} = 110 \text{ kN}$$

$$Q_w = 300 \text{ kN}$$

Ground reactions Z_1, Z_2 per bogies can be determined from the equilibrium of forces and moments about the point A:

$$\sum P_{iz} = 0; Z_1 + Z_2 - Q_{s1} - Q_{s2} - Q_w = 0 \quad (7)$$

$$\sum M_{iA} = 0; -Z_1 \cdot a + Q_{s1} \cdot x_1 + Q_{s2} \cdot x_2 + Q_w \cdot \frac{a}{2} = 0 \quad (8)$$

According to the formulas 9 and 10 ground reactions per bogie are:

$$Z_1 = \frac{Q_{s1} \cdot x_1 + Q_{s2} \cdot x_2}{a} + \frac{Q_w}{2} \quad (9)$$

$$Z_2 = (Q_{s1} + Q_{s2} + Q_w) - Z_1 \quad (10)$$

Reaction per axle can be determined as a half of the reaction per bogie:

$$E_1 = \frac{Z_1}{2} \quad (11)$$

$$E_2 = \frac{Z_2}{2} \quad (12)$$

According to the formulas 11 and 12, reactions for this proposition were calculated as follows:

$$Z_1 = 265,08 \text{ kN}$$

$$Z_2 = 264,92 \text{ kN}$$

$$E_1 = 132,54 \text{ kN}$$

$$E_2 = 132,46 \text{ kN}$$

The final results indicates that the load was not distribute entirely evenly in studied case. Although there were only slight differences between the ground reactions forces Z_1 and Z_2 are (0,16 kN). The maximum bogie ratios were not exceeded according to the rules. The Cargo in presented case can be applied for transportation by any track category with, a maximum allowed speed of 100 km/h.

Conclusions

Rational cargo distribution and securing are main requirements that sender should fulfil before the transportation. Carrier can refuse the transport of a given cargo, when it is loaded inappropriately and therefore the wagon or tracks may get damaged. When cargo is transported by international tracks, the track operator can forbid the transport if the cargo is loaded improperly according to the regulations provided by the operator or UIC.

Based on this research the following rules can be distinguish to provide appropriate load distribution and transportation safety:

- adequate wagon type should be chosen;
- cargo should be distribute as evenly as possible, without maximum load exceeding;
- the loading gauge must not be exceeded;
- appropriate secure system should be provided to prevent the tipping, moving or rolling the goods.

In this research, the maximum amount of units has been proposed to obtain the most rigid formation of goods and to fully distribute wagon loading space. In conclusion on loading length of presented wagon 46 palletised units can be placed. Proposed way of loading through the middle loading clearance is provides the largest space for forklift maneuvering during the whole loading process. Another advantage is that the forklift operator is not obliged to move the side walls after filling side loading space.

The load is not distributed evenly in relation to centre lines. Distance between the transverse centre line of wagon and the load centre of mass is 17 mm. Maximum value of offset in transverse direction according to UIC guideline is approximately 100 mm. Fully evenly distribution would require additional securing techniques, especially during the shunting.

To simplify the scheme loads were presented on figure 5 as two cuboids with centres of masses in its half of lengths. To determine the bogie ground reaction forces, equilibrium of forces and moments was used. The consequence of not even load distribution is the difference between ground reactions, which is 0,08 kN per axles and 0,16 kN per bogies. This values will not cause the overload of any of axles.

LITERATURE

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