

INTERMODAL ROAD-RAIL-SEA LOAD DISTRIBUTION DIAGRAM OF FORTY-FOOT CONTAINER

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Summary: This paper shows intermodal load distribution diagram of maritime container loaded on intermodal wagon and container chassis. Technical characteristics of container are compared with technical characteristics of the wagon and container chassis. Intermodal road – rail - sea load distribution diagram meets conditions of relevant transport modes specific to Europe.

Key words: intermodal transport, load distribution diagram, cargo stowage, maritime container

INTRODUCTION

Construction of load distribution diagrams requires to fulfil not only the technical characteristics of maritime containers, wagons and vehicles but also various requirements defines by legislative measures, guidelines and standards. The paper focus is 40' general purpose container defined according to the standard ISO 830 sec. 4.2.1.1 (1) as “*general cargo container that is totally enclosed and weather-proof, having a rigid roof, rigid side walls, rigid end walls and a floor, having at least one of its end walls equipped with doors and intended to be suitable for the transport of cargo of the greatest possible variety*”.

Cargo center of gravity is important to know when loading containers. The standard ISO 830 in sec. 8.1.3 defines eccentricity of centre of gravity as follows: “*longitudinal and/or lateral horizontal differences between the centre of gravity of any container (empty or loaded, with or without fittings and appliances) and the geometric centre of the diagonals of the centres of the four bottom corner fittings*” (1).

The container payload - P is defined according to the 5.3.3 of ISO 830 as „*maximum permitted mass of payload, including such cargo securement arrangements and/or dunnage as are not associated with the container in its normal operating condition.*“ (1)

1. GROSS MASS, PAYLOADS AND LOAD DISTRIBUTION IN GENERAL PURPOSE FORTY FOOT CONTAINERS

Field analysis of maritime containers in intermodal terminals in Slovakia, Czech Republic and Sweden was performed to study load securing possibilities within maritime containers [cf. (4), (5), (6)].

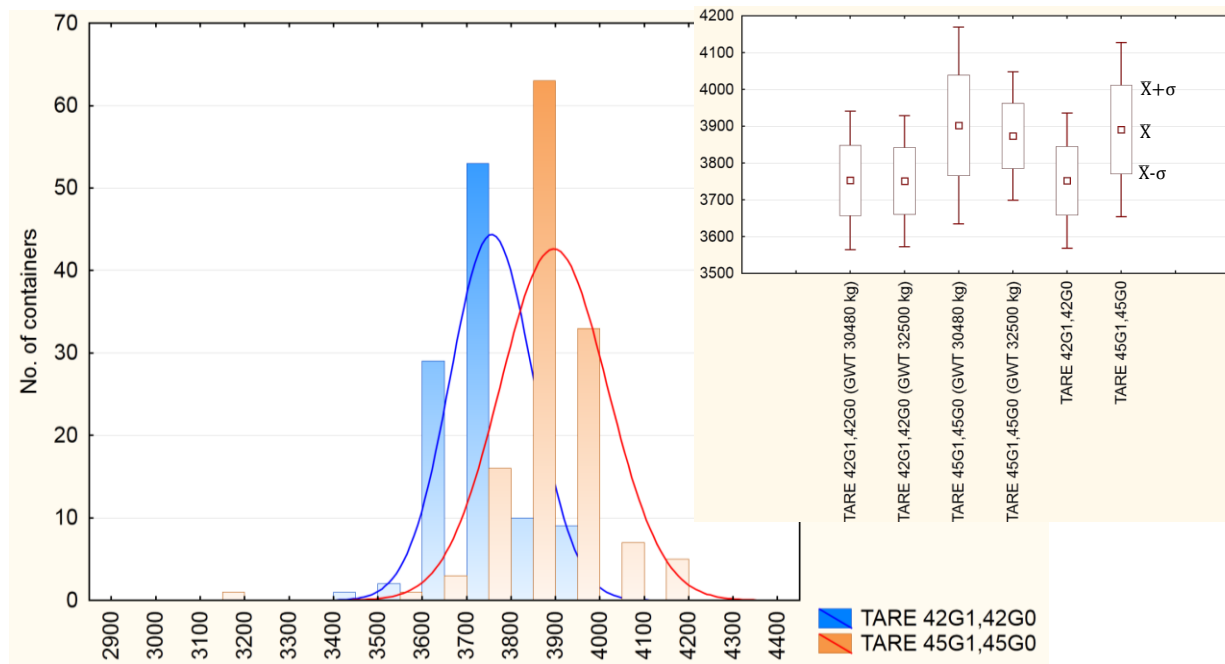
233 different models of forty foot general purpose maritime containers (types 42G0, 42G1, 45G0, 45G1) of different owners have been analysed. Detailed statistics of tare and payload of analysed containers are given in tables and figures below.

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Tab. 1 - Descriptive statistics of TARE of 233 analysed 40' general purpose containers (GM – gross container mass)

Parameter	No. of containers	Mean	Median	Mode	Frequency of Mode	Minimum	Maximum	Lower quartile	Upper quartile
TARE 42G1,42G0 (GM 30480 kg)	65	3752,62	3740	3720	8	3500	4000	3705	3790
TARE 42G1,42G0 (GM 32500 kg)	39	3751,03	3730	3700	8	3600	4000	3700	3790
TARE 42G1,42G0	104	3752,02	3740	multi	11	3500	4000	3700	3790
TARE 45G1,45G0 (GM 30480 kg)	79	3902,06	3900	3890	10	3106	4200	3850	3980
TARE 45G1,45G0 (GM 32500 kg)	50	3873,60	3880	3900	6	3560	4150	3830	3910
TARE 45G1,45G0	129	3891,03	3890	3900	15	3106	4200	3840	3950

Source: Author



Source: Author

Fig. 1 – Distribution of tare mass of 233 analysed 40' containers

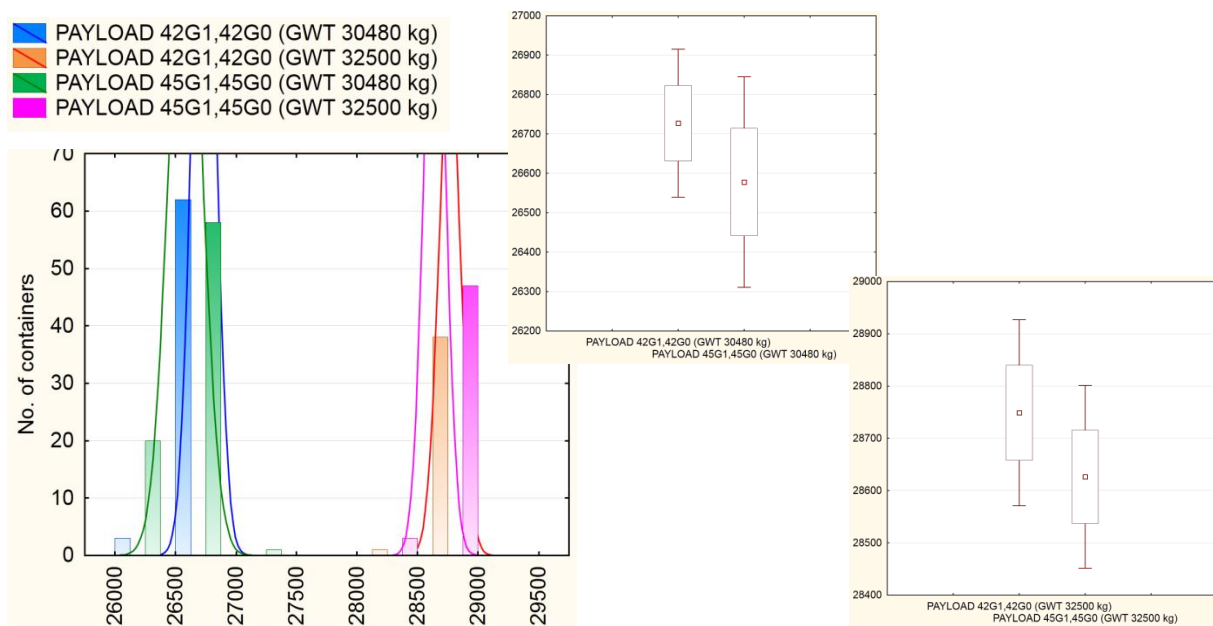
Median TARE of 42G1, 42G0 analysed containers is 3740 kg. Tare of 75% of analysed containers is between 3700 to 3790 kg. High-cube containers (45G0, 45G1) are about 150 kg heavier than 42G0, 42G1 containers. Median TARE of 45G1,45G0 containers is 3890 kg. Tare of 75% of analysed high-cube containers is between 3840 to 3950 kg.

According to the ISO 668 (2) the gross mass (GWT) of such containers is 30480 kg but nowadays the mass 30480 kg and 32500 kg is used very often. This gives technical payloads of 26 tonnes and 28 tonnes minimum.

Tab. 2 - Descriptive statistics of PAYLOAD of 233 analysed 40' general purpose containers

Parameter	No. of containers	Mean	Median	Mode	Frequency of Mode	Minimum	Maximum	Lower quartile	Upper quartile
PAYLOAD 42G1,42G0 (GM 30480 kg)	65	26727,38	26740	26760	8	26480	26980	26690	26775
PAYLOAD 42G1,42G0 (GM 32500 kg)	39	28748,97	28770	28800	8	28500	28900	28710	28800
PAYLOAD 45G1,45G0 (GM 30480 kg)	79	26577,94	26580	26590	10	26280	27374	26500	26630
PAYLOAD 45G1,45G0 (GM 32500 kg)	50	28626,40	28620	28600	6	28350	28940	28590	28670

Source: Author



Source: Author

Fig. 2 – Distribution of payload of 233 analysed 40' general purpose containers

The load shall be distributed in a way not exceeding 60% of mass in a container half according to the standard ISO 3874 (3). For homogeneously stowed load this gives the eccentricity of the cargo centre of gravity 5% of loading length (L). Therefore the cargo centre of gravity shall be from 0,45 L to 0,55 L which shall be also clearly defined in ISO 3874.

However, the container payload depends not only on the container construction itself but also on used transport mode and handling equipment. The focus of this paper is analysis of container payload from construction point of view but also when carried by intermodal wagon and container chassis.

2. LOAD DISTRIBUTION DIAGRAMS

2.1 Load distribution diagram of 40' maritime container

As mentioned in previous chapter container payload, tare and gross mass as well as load distribution rule 60:40 are necessary to construct container load distribution diagram. The diagram limits the position of cargo centre of gravity (CoG) of certain mass to not exceed container gross mass, payload and to meet load distribution requirements. Forty-foot container with a gross mass of 30480 kg, tare of 4000 kg and payload of 26480 kg is used as an example. Maximum container mass on corner fittings respecting load distribution rule 60:40 is calculated as follows:

$$R_{2\max} = 0,45 \cdot P \cdot \frac{l}{L} + \frac{T}{2} = 0,45 \cdot 26480 \cdot \frac{11985}{12030} + \frac{4000}{2} = 13871,43kg \quad (1)$$

$$R_{1\max} = 0,45 \cdot P \cdot \frac{l}{L} + \frac{T}{2} = 0,55 \cdot 26480 \cdot \frac{11985}{12030} + \frac{4000}{2} = 16509,52kg \quad (2)$$

where

$R_{1\max}$... – maximum container gross mass on front wall corner fittings

$R_{2\max}$... – maximum container gross mass on door wall corner fittings

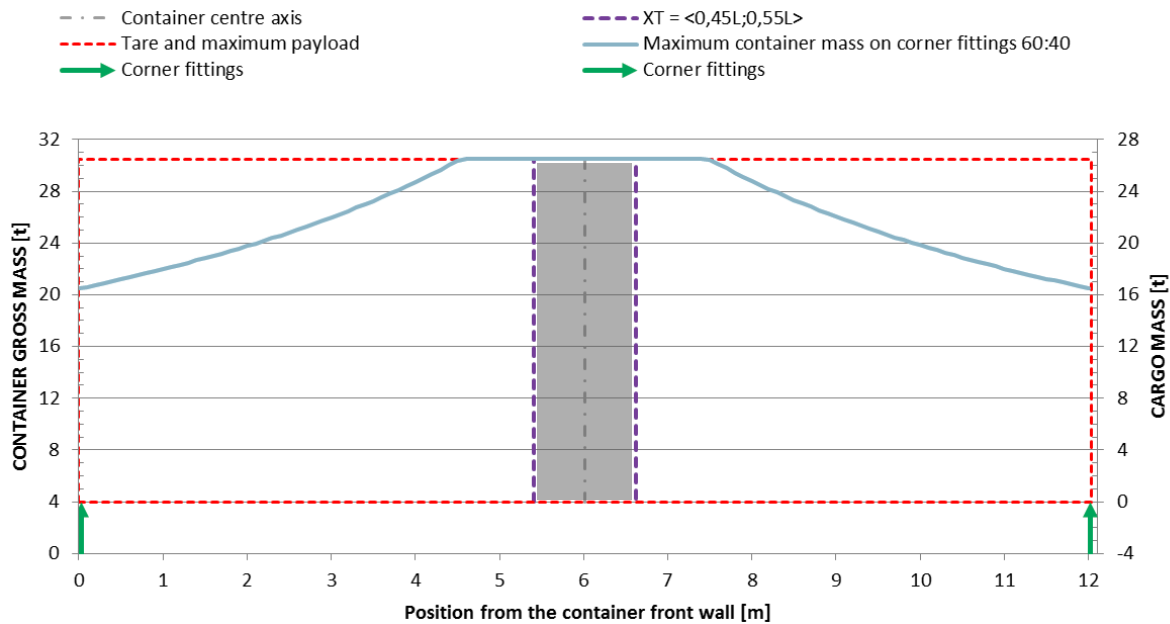
T...Tare mass – mass of empty container including all fittings and appliances associated with a particular type of container in its normal operating condition cf. ISO 830 sec. 5.3.2

P... Payload

L...length of loading platform (12030 mm)

l...distance between corner fittings (11985 mm)

Therefore maximum load on front wall floor container fittings or rear wall floor container fitting is 16,5 tonnes. Maximum mass of the cargo loaded in a container not to exceed maximum corner fitting mass is showed in fig. 3 (blue curve). The second rule is that the position of the centre of gravity shall be from 0,45 L to 0,55 L.



Source: Author

Fig. 3 – Load distribution diagram of 40-foot container (Tare – 4000 kg, GM – 30480 kg)

The result in Figure 1 shows that these boundaries are smaller (within the maximum container payload) than maximum corner fittings mass therefore the centre of gravity of any cargo shall be located in a grey area.

2.2 Load distribution diagram of two-axle container wagon – Lgs

Lgs container wagon of Slovak rail operator ZSSK Cargo a.s. (9) is used to construct load distribution diagram. This two-axle wagon is suitable example because it is possible to load 40' container only and wagon payload is lower than container gross mass.

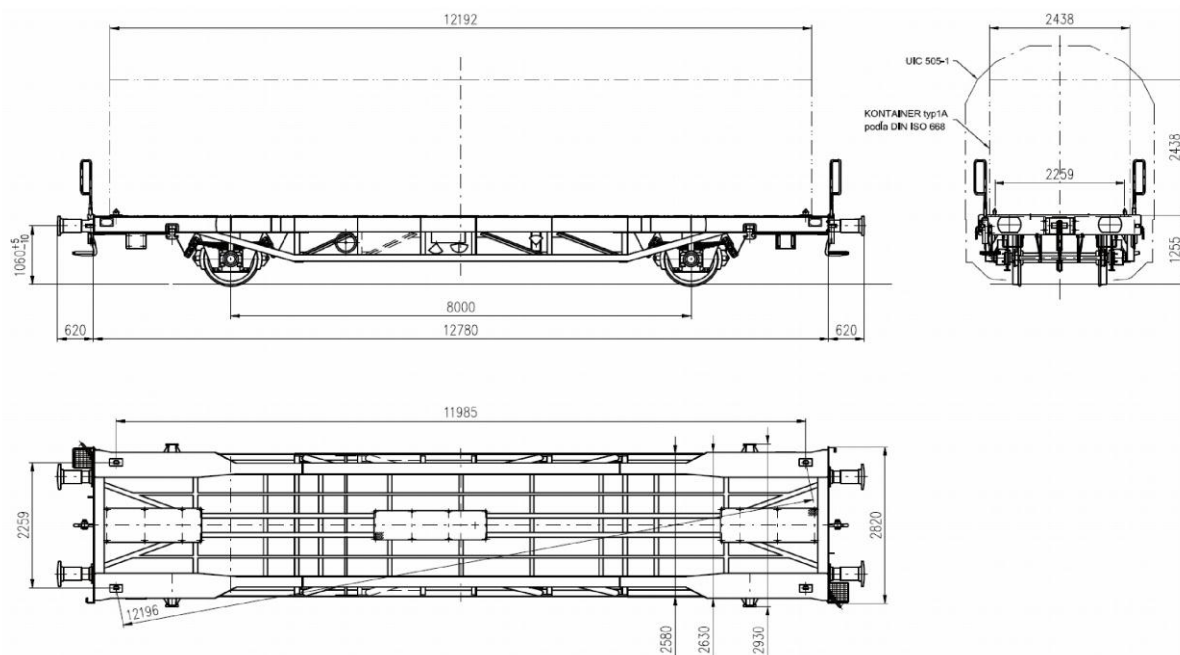
Load distribution diagram of two axle container wagon is influenced by following parameters:

- wagon tare,
- wagon gross mass for different route category (A, B, C, D), train speed (S, SS) and selected rail operators,
- wagon payload for different route category (A, B, C, D), train speed (S, SS) and selected rail operators,
- maximum authorised axle mass per route category (A, B, C, D),
- maximum uneven axle load 2:1 according to UIC Loading guidelines, (12)
- axle tare mass,
- wagon wheel base,
- distance from the end of the loading platform to neighbouring axle,
- length of the loading platform,
- position of wagon container locks.

Tab. 3 – Technical characteristics of Lgs container wagon

Wagon type	Lgs
Number of axles	2
Axle wheelbase	8 m
Loading length	12,78 m
Container locs distance	11,985 m
Wagon tare	10,8 t
Axle tare	5,4 t
Wagon payload	
- A	21,30 t
- B	25,30 t
- C	29,20 t
Wagon gross mass	
- A	32,10 t
- B	36,10 t
- C	40,00 t
Maximum axle mass	
- A	16,00 t
- B	18,00 t
- C	20,00 t

Source: (9)

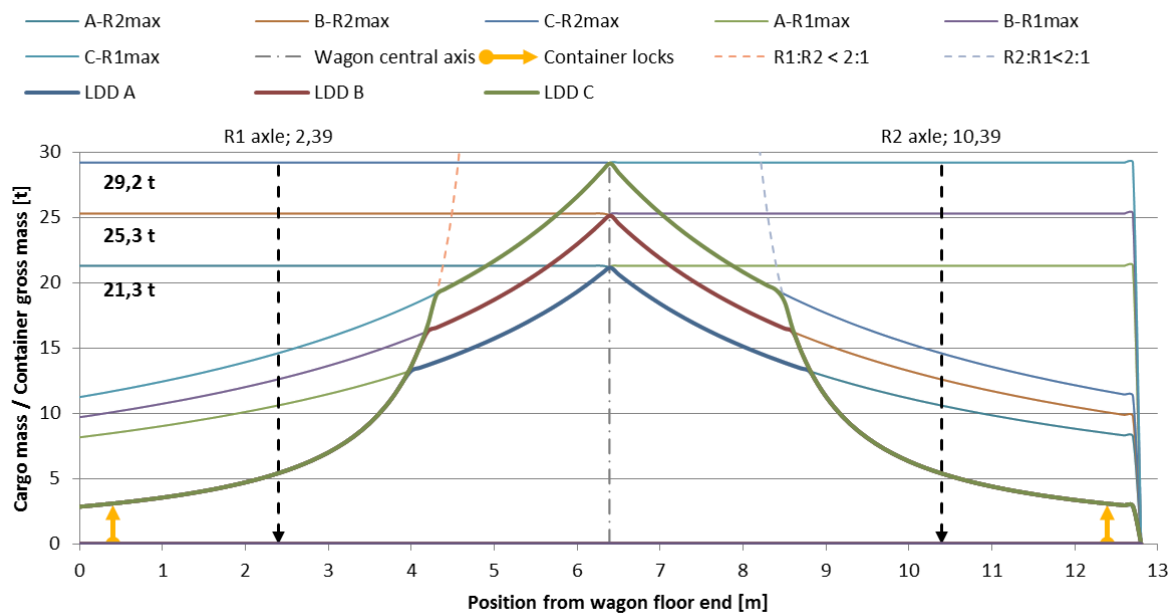


Source: (9)

Fig. 4 – Lgs container wagon of ZSSK Cargo a.s.

Load distribution diagram of Lgs container wagon is defined by:

- maximum axle mass (R_{1max} , R_{2max}) per different route category (A, B, C curves for R_{1max} , R_{2max})
- maximum payload for different route category
- $R_1 : R_2 < 2:1$ and $R_2 : R_1 < 2:1$ curves



Source: Author

Fig. 5 – Load distribution diagrams (LDD) of Lgs container wagon for different route categories (including construction curves)

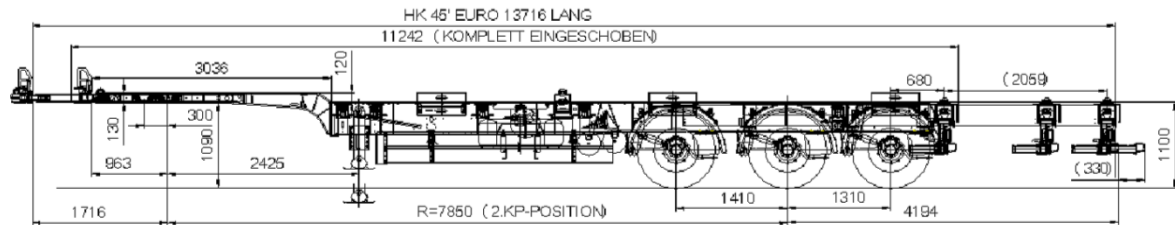
Load distribution diagrams of Lgs container wagon show area where cargo centre of gravity for different cargo mass must be located. This area is bounded by maximum axle mass per different route category and by maximum uneven axle load 2:1. The axle curves meet in one point which presents disadvantage because if we want to load the cargo with the highest possible mass its center of gravity must be right in the middle of the wagon. For example if CoG of load of 29,2 t is 6,7 m (6,39 is middle axis) from wagon floor end this creates axle mass $R_1 = 18,9$ t and $R_2 = 21,1$ t which is higher than 20 tonnes permitted per route category C.

2.3 Load distribution diagram of semi-trailer container chassis

Technical characteristics of Schmitz S.CF GOOSENECK EURO container chassis of type S.CF 45' EURO (10) are used. Load distribution diagram of semi-trailer is influenced by following parameters:

- container chassis tare (5,6 t),
- maximum king-pin load technical suitable for three-axle tractor (15 tonnes) and king-pin load influenced by two-axle tractor (9,8 tonnes – two-axle tractor tare of 8,2 t supposed) – B curves in figure below,
- maximum gross combination mass (40 t, 44 t or semi-trailer gross mass 39 t) – C axis,
- king-pin and triple axle tare (1,6t / 4 t supposed),
- maximum triple axle load (3 x 9 t) – D curve,
- length of loading platform (13,716 m),
- position of container twist-locks for 40' container,

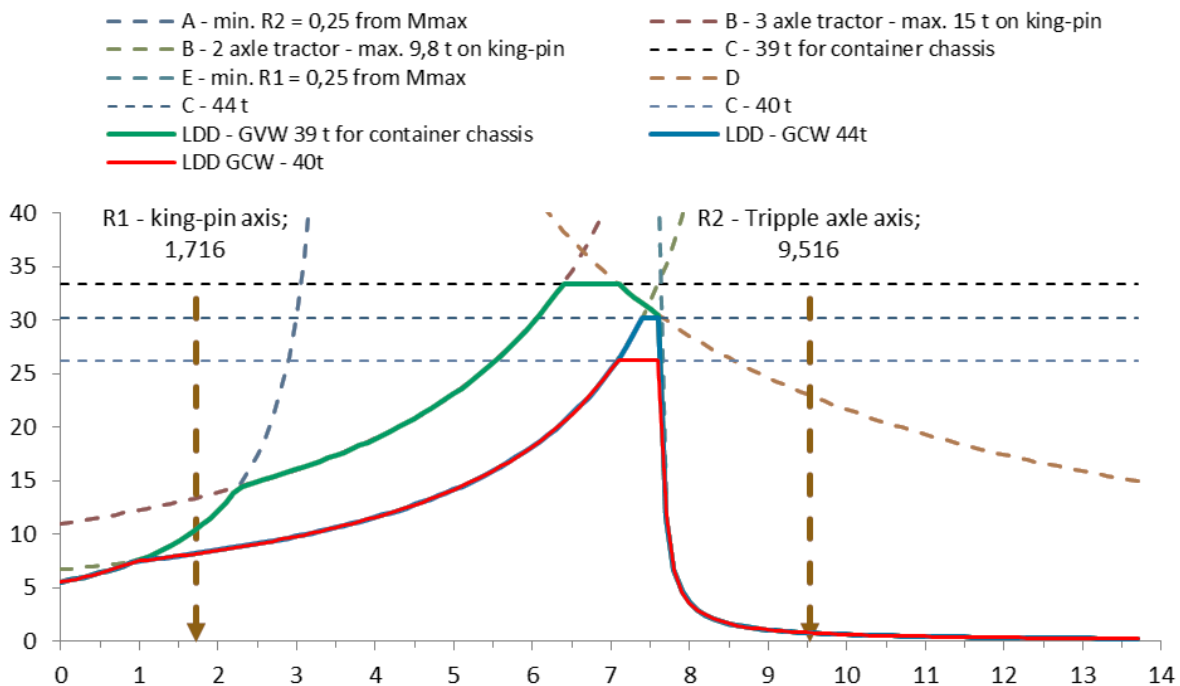
- distance from maximum front container face to king-pin and from 40' container front face to king-pin axis (1,716 m / 0,963 m),
- distance king-pin to first axle and between axles (7,85 m / 1,41 m / 1,31 m),
- minimum king-pin and triple axle load (25% / 25% of maximum semi-trailer mass is chosen) – E and A curves in figure below.



Source: (10)

Fig. 6 – Schmitz S.CF GOOSENECK EURO

Three alternatives of load distribution diagrams of selected container chassis are shown in figure above. Permissible load on king-pin determines if it is necessary to use two-axle or three-axle tractor when it is possible to use permissible technical load on king-pin 15 tonnes. Because of maximum allowed weight of 18 tonnes for two axle tractor limits permissible load on king-pin to 9,8 tonnes (8,2 tonnes tractor tare supposed) when two axle tractor is used. Maximum gross combination weights and maximum semi-trailer gross weight are showed as C axis and limits the payload of container chassis.



Source: Author

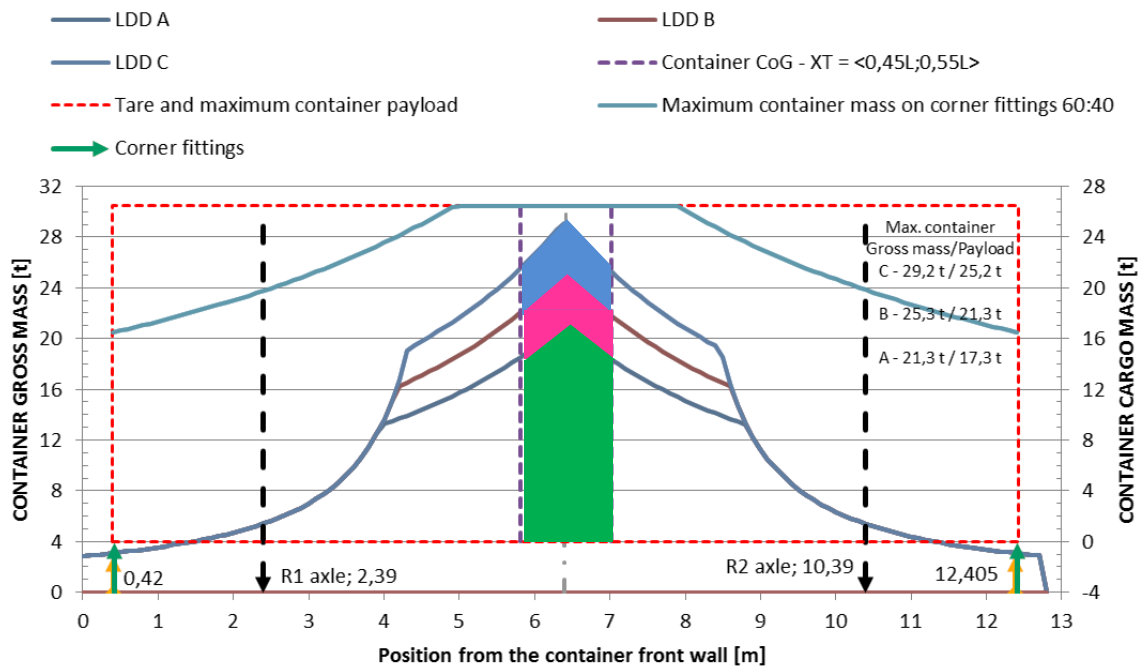
Fig. 7 – Three alternatives of load distribution diagrams (LDD) of container chassis

Three alternatives of load distribution diagrams of selected container chassis are shown in figure above. Permissible load on king-pin determines if it is necessary to use two-axle or three-axle tractor when is possible to use permissible technical load on king-pin 15 tonnes. Because of maximum allowed weight of 18 tonnes for two axle tractor limits permissible load on king-pin to 9,8 tonnes (8,2 tonnes tractor tare supposed) when two axle tractor is used. Maximum gross combination weights and maximum semi-trailer gross weight are showed as C axis and limits the payload of container chassis.

3. INTERMODAL LOAD DISTRIBUTION DIAGRAMS

3.1 Intermodal load distribution diagram of 40-foot maritime container carried on two-axle Lgs container wagon

Intermodal load distribution diagram of 40-foot maritime loaded on container wagon is possible to construct from container and wagon LDD's. Here we have to take into consideration also the container tare because this also presents the cargo for the wagon. In the diagram below we can see container GM on right vertical axis and cargo mass on left vertical axis so it is possible to simultaneously check loading of container as well as wagon with the container.



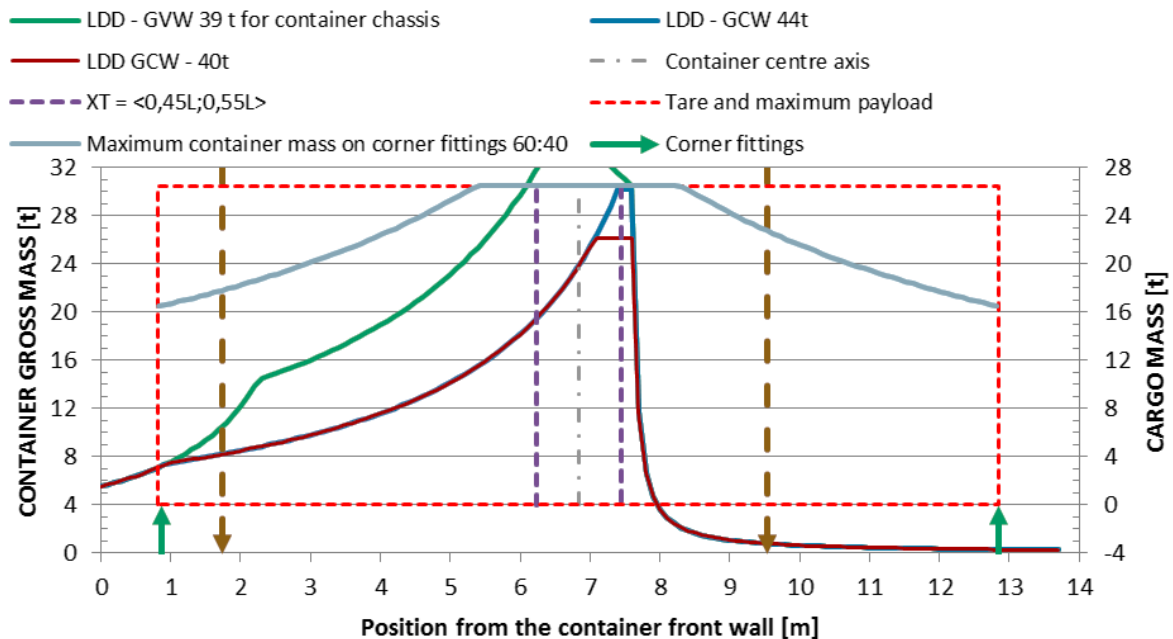
Source: Author

Fig. 8 – Load distribution diagram of 40-foot maritime container loaded on Lgs container wagon

When container and wagon LDD's are combined then three area of position of cargo centre of gravity for different mass are bounded by LDD curves for this type of wagon constructed for route categories A, B, C. Container LDD is displaced vertically by container tare mass.

3.2 Intermodal load distribution diagram of 40-foot maritime container carried on container chassis

Intermodal load distribution diagram of 40-foot maritime container loaded on container chassis is possible to construct from container and chassis LDD's. Here we have to take into consideration also the container tare weight because this also presents the cargo for container chassis. Again container gross mass is in right vertical axis and cargo mass on left vertical axis in the diagram below. Therefore it is possible to check loading of container as well as chassis with the container.



Source: Author

Fig. 9 – Load distribution diagram of 40-foot maritime container loaded on container chassis

When container and chassis LDD's are combined then correct load distribution to maximum payload is possible only when three-axle tractor is used. When maximum king-pin load is limited by two-axle tractor than the centre of gravity should be eccentrically towards container doors and almost on the limits of container load distribution. With higher cargo mass the risk of incorrect unloading increases. When lighter two-axle tractor is used the loading situation looks more favourably for gross combination weight 40 tonnes but for GCW 44 tonnes there is not big difference. In case that the cargo centre of gravity is in first container half (close to front wall where loading with container doors towards back is supposed) than the tractor is overloaded (see fig. 9).

3.3 Intermodal load distribution diagram of 40-foot maritime container carried on two-axle container wagon and container chassis

Intermodal road-rail-sea load distribution diagram is constructed when LDD of container, container wagon and container chassis are combined. Here the limitations for loading on wagon and container chassis are again seen.

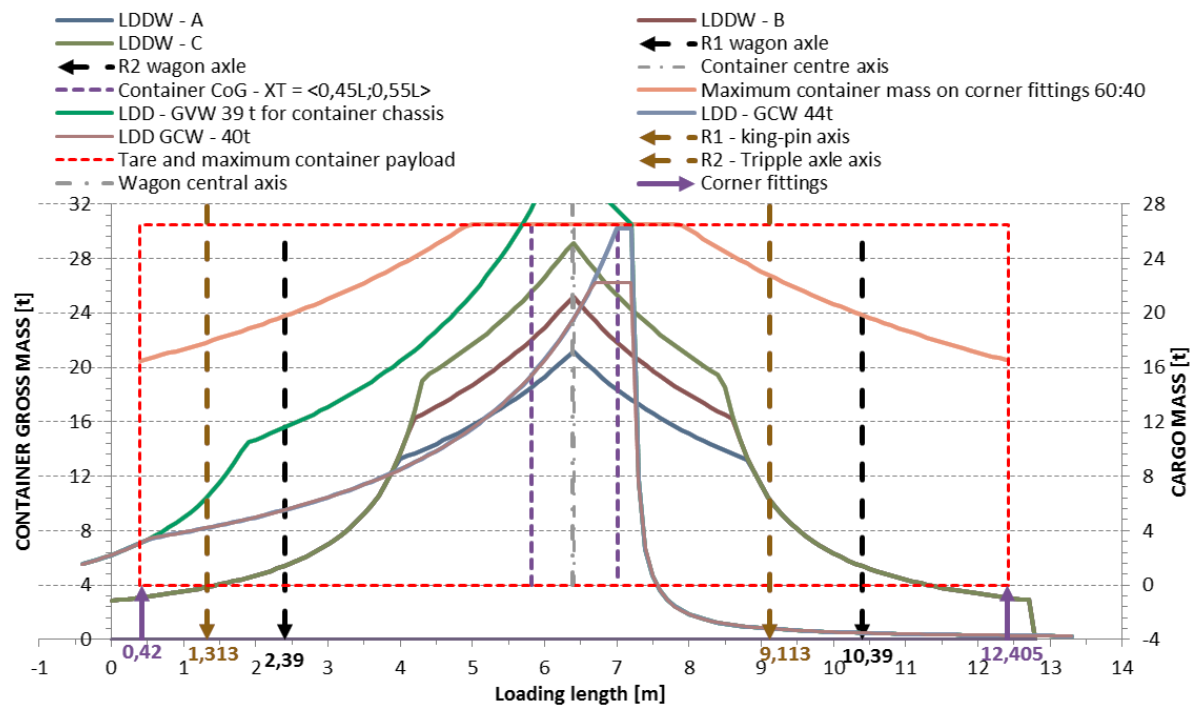


Fig. 10 – Load distribution diagram of 40-foot maritime container loaded on container wagon and container chassis

The figure above shows all LDD's and we can clearly decide that maximum cargo mass in this case is 26,2 tonnes limited by container chassis and gross combination weight of 40 tonnes. Maximum eccentricity of the cargo centre of gravity shall be maximum 3,6 % which is limited by maximum axle load of railway wagon for route category C.

CONCLUSIONS

The analysis of load distribution of 40-foot maritime container, Lgs container wagon and Schmitz S.CF GOOSENECK EURO showed that it is possible to construct intermodal load distribution diagram where load distribution requirements of container, wagon and container chassis are fulfilled. Workers loading containers for road, rail and sea transport must realize that incorrectly loaded container means overloading of wagon or container chassis axles or wagon/chassis payload, especially when two-axle wagons or two-axle tractors are used. Present analysis has showed that it is not possible to utilize full container technical payload because of technical limits of Lgs container wagon. When suitable vehicle combination is used during road carriage maximum payload of container can be achieved but only in countries where gross combination weight is higher than 40 tonnes and with three axle tractors.

REFERENCES

- (1) ČSN ISO 830:2000 Freight containers – Vocabulary.
- (2) STN ISO 668 Series 1 freight containers. Classification, dimensions and ratings (November 2000).
- (3) STN ISO 3874 Series 1 freight containers. Handling and securing (November 2002).

- (4) Jagelčák, J., Vrábek J.: *Cargo securing devices in standard twenty foot general purpose maritime containers* In: Transport & logistics = Doprava a logistika. - ISSN 1451-107X. - 2011. - Č. 9 mimoriadne (2011), s. 492-499.
- (5) Jagelčák, J., Vrábek, J., Fazekaš, M.: *Loading and cargo securing devices in standard forty foot general purpose maritime containers*. In: Doprava a spoje [elektronický zdroj] : internetový časopis. - ISSN 1336-7676. - 2011. - Č. 2 (2011), s. 28-38. - Spôsob prístupu: <http://fpedas.uniza.sk/dopravaaspoje/2011/2/Jagelcak.pdf>.
- (6) Jagelčák, J.: *Load securing of big-bags with dangerous goods in maritime containers for road, rail and deep sea carriage* In: MOSATT 2011 : modern safety technologies in transportation : proceedings of the international scientific conference ISSN 1338-5232 Volume 4, 20-22 September 2011, Zlata Idka, Slovakia. - Košice: Suprema, 2011. - ISBN 978-80-970772-0-4. - S. 164-171. Zborník bol vydaný aj na CD-ROM, ISBN 978-80-970772-1-1.
- (7) Jagelčák, J.: *Intermodal load distribution diagram of forty-foot container loaded on two-axle container wagon of Lgs type* In: Horizons of Railway Transport: Scientific Papers of the University of Žilina, Faculty of Operation and Economics of Transport and Communications. - ISSN 1338-287X. – No.1 Vol. 2 (2011), pp. 53-59.
- (8) Jagelčák, J. , Vrábek, J., Fazekaš, M.: *Intermodal load distribution diagram of forty-foot container loaded on container chassis* In: Zborník príspevkov a posterov z 6. vedeckej konferencie Cestná a mestská doprava a trvaloudržiateľný rozvoj - CMDTUR 2012. Žilina Stráža 19.04.-20.04.2012. Žilinská univerzita, 2012. p. ISBN 978-80-554-0512-4
- (9) Lgs container wagon specifications. ZSSK Cargo a.s. <<http://www.zscargo.sk/files/katalog/2011/lgs.pdf>> (March 2012).
- (10) S.CF Gooseneck Container Chassis Product Range. Schmitz Cargobull A.G. <http://www.cargobull.com/en/media_centre/download-center.php?sektion=fahrzeuge#> (March 2012).
- (11) Jagelčák, J. and Dávid, A. and Rožek, P. *Námorné kontajnery*. Žilinská univerzita v Žiline (2010). ISBN 978-80-554-0207-9.
- (12) UIC Smernice nakladnia (Loading guidelines). Zväzok 1 (Volume 1): Zásady (Basics).
- (13) VDI 2700 Ladungssicherung auf Straßenfahrzeugen. Blatt 4 - Lastverteilungsplan (Mai 2000).
- (14) VDI 2700 Ladungssicherung auf Straßenfahrzeugen. Blatt 4 – Lastverteilungsplan - Entwurf (September 2008).

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