Load Distribution in General Purpose Maritime Container and the Analysis of Load Distribution on Extendable Semi-trailer Container Chassis Carrying Different Types of Containers

Raspodjela tereta na višenamjenskim pomorskim kontejnerima i analiza raspodjele tereta na produžnom kontejnerskom podvozju poluprikolica koje nose različite vrste kontejnera

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Summary

This paper deals with the load distribution requirements for loading of general purpose maritime container to be suitable for handling in terminals and for road carriage. Intermodal load distribution diagrams container-vehicle in container longitudinal axis are constructed on the example of 40′ general purpose maritime container. The analysis of load distribution of two 20′ containers of different gross mass in the longitudinal axis of extendable container chassis and analysis of load distribution where 20′, 40′ and 45′ containers are carried by extendable container chassis is also presented. This paper is the result of the project implementation: Centre of excellence for systems and services of intelligent transport II., ITMS 26220120050 supported by the Research & Development Operational Programme funded by the ERDF.

KEY WORDS

maritime container
load distribution
eccentricity of centre of gravity
intermodal load distribution diagram
container chassis

Sažetak

U članku se govori o zahtjevima raspodjele tereta pri utovaru na višenamjenskim pomorskim kontejnerima kako bi oni bili pogodni za rukovanje u terminalima i za cestovni prijevoz. Dijagrami intermodalne raspodjele tereta na kontejneru po uzdužnoj osi izrađeni su na primjeru 40-stopnog višenamjenskog kontejnera. Analizirana je raspodjela tereta na dva 20-stopna kontejnera različite bruto mase po uzdužnoj osi produžnog podvozja kontejnera i također je prikazana analiza raspodjele tereta na 20, 40 i 45-stopnim kontejnerima s produžnim podvozjima. Ovaj rad rezultat je provedbe projekta: Centar izvrsnosti za sustave i usluge pametnog transporta II., ITMS 26220120050 uz potporu Operativnog programa za istraživanje i razvoj, financiranog sredstvima ERDFa.

KLJUČNE RIJEČI

pomorski kontejner
raspodjela tereta
eksentricitet centra mase
dijagram intermodalne raspodjele tereta
kontejnersko podvozje

INTRODUCTION / *Uvod*

Incorrect load distribution of maritime container has direct impact on safety of handling and carriage in terminals, in road, rail and sea transport. Wrong declared container gross mass often means overloading of vehicles, railway wagons, vessels and handling equipment in terminals. According to Radišic large container vessels carry thousands of containers on deck and failure of the lashing system can cause enormous expenses as result of damage and container loss. The consequence of single container lashing breakdown generates the domino effect on the adjacent stacks which then causes big damage. [2].

The Maritime Safety Committee (MSC) of International Maritime Organisation approved, for adoption at MSC 94 in November 2014, draft amendments to SOLAS chapter VI to require mandatory verification of the gross mass of containers, either by weighing the packed container or by weighing all packages and cargo items and adding the tare mass. The Committee also approved related draft guidelines regarding the verified gross mass of a container carrying cargo, to be issued as an MSC circular. [3]

To fulfil load distribution requirements for the cargo centre of gravity not only the technical characteristics of maritime containers, wagons and vehicles but also various requirements defined by legislative measures, guidelines and standards shall be followed. The paper's focus is to present how to combine different load distribution requirements for loading of general purpose maritime container when handled in terminals and carried by road. 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". [4]

It is important to know the cargo centre of gravity and container centre of gravity 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". [4]

According to the ILO Safety in the supply chain in relation to packing of containers study [8], the data for eccentricity of container centre of gravity were collected at one terminal in the United Kingdom. From all containers weighed by container crane 65 % of containers had eccentricity of centre of gravity up to 5 % which is an acceptable limit. However, 20 % of containers analysed had eccentricity of centre of gravity from 5 % to 10 % and 15 % of containers above 10 %. The study also states that 3 % of the containers had eccentricity of centre of gravity more than 20 % which presents considerable safety risk during carriage and handling. The study does not provide the information about the direction of the eccentricity of centre of gravity whether it is towards the container doors or towards the container front end which is an important issue when considering vehicle or wagon axle loads.

When container gross mass was analysed during the same work it was found that approximately 17% of the containers weighed had a total mass of between 25 and 30 tonnes and about 4 % of containers had a total mass of between 30 and 35 tonnes. The container gross mass of 20' (22G1) and 40' (42G1, 45G1) general purpose maritime containers is 30480 kg and 32500 kg nowadays. This means that there were also containers with exceeded maximum gross mass.

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." [4]

This definition states container technical payload and technical maximum cargo mass which is indicated on container CSC plate and the doors. But when container is carried by road and rail, vehicles and wagons (mainly two-axle wagons) can influence maximum cargo mass because of the vehicle/wagon gross mass or axle loads (see Table 2).

To fulfil the load distribution requirements in intermodal transport, for maritime container it means not to exceed the container gross mass, maximum allowed eccentricity of container centre of gravity and floor loadings for concentrated loads. In case when container is carried on road vehicle, than the vehicle, trailer and the combination of gross mass, maximum and minimum allowed axle loads must be followed. When the container is carried by rail, than the wagon gross mass, mass per wagon meter, maximum allowed axle load per route category and speed and maximum allowed uneven loading of axles or boogies shall be followed.

LOAD DISTRIBUTION DIAGRAMS / *Dijagrami raspodjele tereta*

LOAD DISTRIBUTION DIAGRAMS OF MARITIME CONTAINER / *Dijagrami raspodjele tereta na pomorskim kontejnerima*

Load distribution diagrams can be constructed for maritime container, railway wagon and road vehicle and in certain cases it is possible to combine them to intermodal load distribution diagrams container-vehicle, container-wagon or container-vehicle-wagon. Intermodal load distribution diagram shows areas where load centre of gravity (further as CG) must be located with regard to the requirements for loading of container, vehicle and wagon.

CG of loaded container in longitudinal axis is $x_{T_{C+L}}$ calculated as follows:

$$x_{T_{C+L}} = \frac{0{,}5 \cdot L \cdot T + \sum_{i=1}^{n}(x_i \cdot m_i)}{T + \sum_{i=1}^{n} m_i} \text{ [m]} \quad (1)$$

where:
L...internal length of loading platform [m],
T...tare – empty general purpose container mass [t],
xi...distance of load unit i from the front wall [m],
mi...mass of load unit i [t].

The eccentricity of CG can be defined as follows:

$$e_{x_T} = \left(0{,}5 - \frac{x_T}{L}\right) \text{ [-]} \quad (2)$$

Eccentricity of CG of loaded container $e_{x_{T_{C+L}}}$ changes with the cargo mass with regard to container tare in case of constant eccentricity of load CG. The relation between the eccentricity of CG of loaded container $e_{x_{T_{C+L}}}$ and eccentricity of CG of the load $e_{x_{T_L}}$ in longitudinal axis using formulas (1) and (2) is as follows:

$$e_{x_{T_{C+L}}} = 0{,}5 - \left(0{,}5 - e_{x_{T_L}}\right) \cdot \frac{m}{T+m} - \frac{x_{T_C} \cdot T}{L(T+m)} \text{ [-]} \quad (3)$$

where:
m…mass of the load in container.

In case that the CG of empty container is in half of container $x_{T_C} = 0{,}5L$ formula (3) can be simplified to:

$$e_{x_{T_{C+L}}} = e_{x_{T_C}} \cdot \frac{m}{T+m} \text{ [-]} \quad (4)$$

and for the eccentricities:

$$e_{x_{T_L}} = e_{x_{T_{C+L}}} \cdot \frac{T+m}{m} \text{ [-]}$$

New IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units defines the eccentricity of container centre of gravity as follows: "Where freight containers, including flatracks or platforms, will be lifted and handled in a level state during transport, the cargo should be so arranged and secured in the freight container that its joint centre of gravity is close to the mid-length and mid-width of the freight container. The

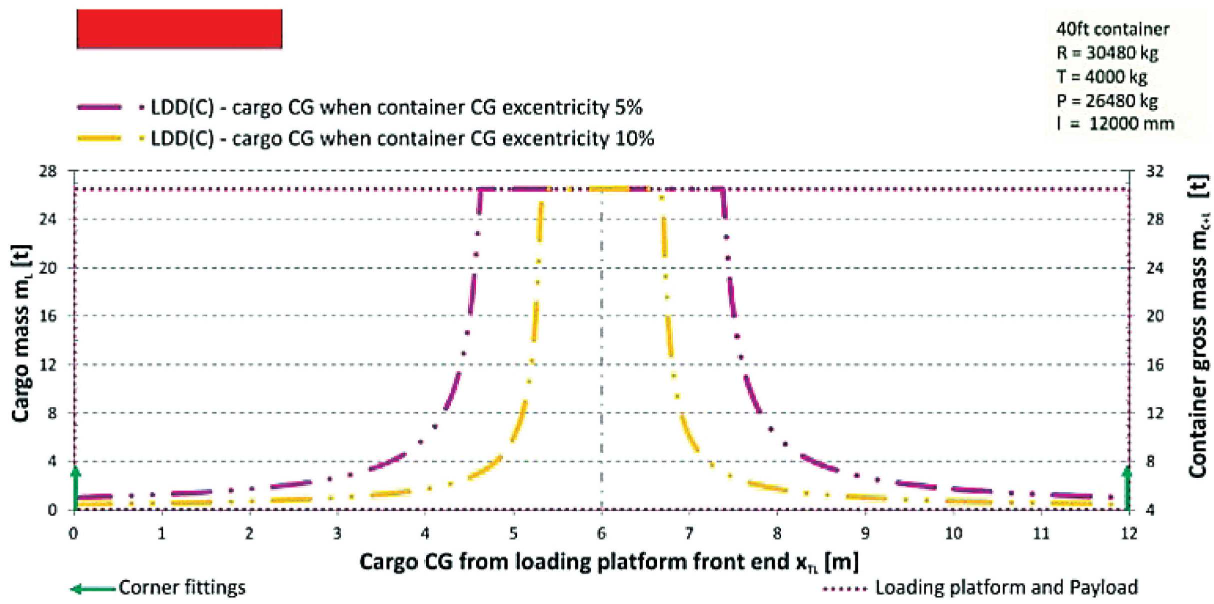

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Figure 1 Example of load distribution diagrams (LDD) for 40' general purpose maritime container (42G1, 45G1)

Slika 1. Primjer dijagrama raspodjele tereta (LDD) za 40 stopni višenamjenski pomorski kontejner (42G1, 45G1)

eccentricity of the centre of gravity of the cargo should not exceed ±5% in general. As a rule of thumb this can be taken as 60% of the cargo's total mass in 50% of the freight container's length. Under particular circumstances an eccentricity of up to ±10% could be accepted, as advanced spreaders for handling freight containers are capable of adjusting for such eccentricity." [5]

Hapag-Lloyd in [9] stipulates that cargo CG shall be in container longitudinal axis for 20' container maximum 60 cm from the centre and for 40' container maximum 90 cm from the centre. This presents a cargo CG eccentricity of around 10 % for 20' containers and 7,5 % for 40' containers.

Figure 1 shows the load distribution diagram for 40' general purpose maritime containers, which presents the boundaries for cargo CG eccentricity of 5 % and 7.5 % and for cargo CG when container CG eccentricity is 5% and 10%.

When we compare the boundaries of cargo CG eccentricities with container CG eccentricities especially for low cargo masses because of container tare mass cargo, CG eccentricity can be higher. From practical point of view the packer can follow cargo CG eccentricities and he never exceeds container CG eccentricities. Maximum distance in longitudinal axis of cargo CG from container centre for different eccentricities is given in Table 1.

Container load distribution diagrams can be also constructed with the same principle in transverse axis. Combine load distribution diagrams which take into consideration both axis can also be constructed. Such diagrams are presented for 40' container on figure 2.

However, in the combined road-rail-sea transport, the packer shall load the container which comes to the loading site on road vehicle, than it continues from the terminal to the port of departure by rail and then by sea. Usually the first part of combined transport presents a problem in terms of not exceeding gross combination mass and axle loads. This means that container technical payload and stipulated cargo CG eccentricities for safe handling of containers cannot always be used as a requirement for road and rail container transports. Maximum cargo mass in 40' container technical and when carried by selected vehicle combination and rail wagon is given in Table 2 as an example. When such a container shall be transported by such combination of vehicle and wagon, than the maximum cargo mass is 25200 kg (route category C is considered for rail transport) even if container technical payload is 26480 kg.

Table 3 gives maximum technical cargo mass which is possible to load to 20' and 40' general purpose maritime containers rounded down to the nearest whole tonnes. The data were acquired from the sample of 500 containers series (unique manufactured series) of different shipping lines and lessors inspected by the authors.

Table 1 Maximum distance in longitudinal axis of cargo CG from container centre for different cargo CG eccentricities

Tablica 1. Najveća udaljenost po uzdužnoj osi tereta CG od centra kontejnera za različite eksentricitete tereta CG

Container length	Container size and type code ISO 6346	cargo CG eccentricity		
		5 %	7,5 %	10 %
20'	22G0, 22G1, 22V0, 22U1, 22U6	30 cm	45 cm	60 cm
40'	42G0, 42G1, 42U1, 42U6 45G0, 45G1, 45U6	60 cm	90 cm	120 cm

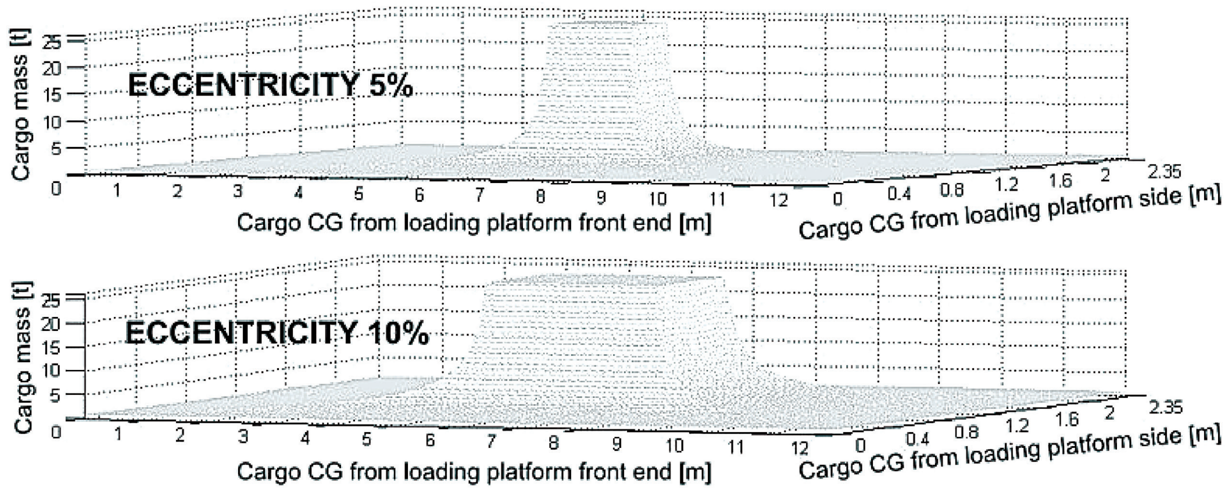

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Figure 2 Load distribution diagrams for 40' general purpose maritime container for longitudinal and transverse axis for maximum 5% and 10% eccentricity of loaded container

Slika 2. Dijagrami raspodjele tereta za 40 stopne višenamjenske pomorske kontejnere za uzdužnu i poprečnu os za maksimalno 5% i 10% eksentriciteta napunjenog kontejnera

Table 2 Example of maximum cargo mass in 40' container carried by road vehicle and rail wagon

Tablica 2. Primjer najveće mase tereta kod 40 stopnog kontejnera na cestovnom vozilu i željezničkom vagonu

	40' container 42G1	**two axle tractor + three axle container chassis VOLVO FH 12 + KRONE SDC 27 ELTU***	**two axle container wagon Lgs [10]**
tare	4000 kg	13 500 kg 17 500 kg (with container)	10800 kg 14800 kg (with container)
gross mass	30480 kg	maximum allowed gross combination mass GCM_{40} - 40 000 kg GCM_{42} - 42000 kg GCM_{44} - 44 000 kg	Route categories A - 32000 kg B - 36000 kg C - 40000 kg
maximum cargo mass in container	26480 kg	GCM_{40} - 22500 kg GCM_{42} - 24500 kg GCM_{44} - 26480 kg	A - 17200 kg B - 21200 kg C - 25200 kg

* data acquired by own weighing

Source: authors

Table 3 Container tare and maximum cargo mass of 20' and 40' general purpose containers

Tablica 3. Masa kontejnera (tara) i najveća masa tereta kod 20 i 40 stopnih višenamjenskih kontejnera

Container size and type code ISO 6346	**Number of container series inspected**	**Container tare**	**Maximum cargo mass at container gross mass 30480 kg**	**Maximum cargo mass at container gross mass 32500 kg**
22G1, 22G0, 25G1	200	2000 - 2400 kg	28000 kg	30000 kg
42G1, 42G0	134	3500 - 4140 kg	26000 kg	28000 kg
45G1, 45G0	166	3560 - 4200 kg	26000 kg	28000 kg

Source: authors

Table 4 Maximum cargo mass in 40′ general purpose containers (42G1, 45G1) carried by five axle vehicle combinations
Tablica 4. Maksimalna masa tereta u 40 stopnim višenamjenskim kontejnerima (42G1, 45G1) na kombiniranim petoosovinskim vozilima

Maximum allowed gross combination mass	Maximum cargo mass at container gross mass 30480 kg	Maximum cargo mass at container gross mass 32500 kg
40 tonnes	22-25 tonnes	
42 tonnes	24-26 tonnes	24-27 tonnes
44 tonnes	26 tonnes	27-28 tonnes

LOAD DISTRIBUTION DIAGRAM OF CONTAINER SEMI-TRAILER / *Dijagram raspodjele tereta kontejnera na polu-prikolicama*

On the basis of the relevant legislation at EU level it was decided to support the development of combined transport in several areas. One of them is to make combined transport more attractive by offering higher maximum permissible mass of the combination of 4 tonnes. At present, it appears that this advantage is no longer enough and covers only part of the combined transport mostly oriented to maritime transport of 40′ containers. With the continuous increase of continental combined transport, the question arises to change the relevant legislation, as it does not give benefit just where it appears increasingly necessary.

As a basic document in this regard is the Council Directive 96/53/EC laying down for certain road vehicles circulating within the Community the maximum authorized dimensions in national and international traffic and the maximum authorized weights in international traffic. Maximum permissible gross combination mass of 44 tonnes is permitted under the following conditions. According to point 2.2.2 of Annex I of the directive this applies to „three-axle motor vehicle with two or three-axle semi-trailer carrying a 40-foot ISO container as a combined transport operation".

Current directive restricted the use of a total gross combination mass of 44 tonnes at three levels, namely the choice of intermodal transport unit - 40′ ISO container, the vehicle selection - 5 or 6 axle articulated vehicle (due to the 40′ ISO container) and the mode of transport - combined transport.

This means that according to the directive gross combination mass of 44 tonnes cannot be used when 20′, 30′, 45′ containers and other intermodal transport units as swap-bodies, intermodal semi-trailers are carried by road. In this case the maximum gross combination mass of 40 tonnes shall be used.

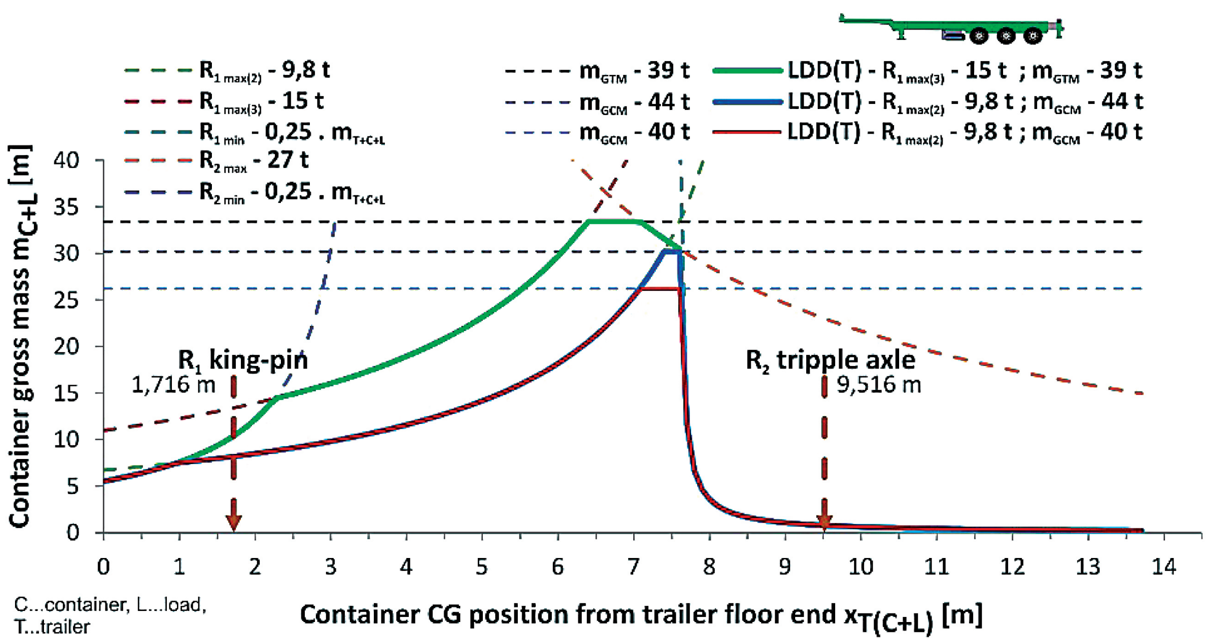

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Figure 3 Example of load distribution diagrams for container chassis SCHMITZ S.CF GOOSENECK 45′ EURO [6] with trailer gross mass of 39 tonnes and three-axle tractor (green curve), gross combination mass of 40 tonnes and two axle tractor (red curve) and gross combination mass of 44 tonnes and two-axle tractor (blue curve)
Slika 3. Primjer dijagrama raspodjele tereta za podvozje kontejnera SCHMITZ S.CF GOOSENECK 45′ EURO [6] sa 39 tona bruto masom prikolice i troosovinskim traktorom (zelena krivulja), kombiniranom bruto masom od 40 tona i dvoosovinskim traktorom (crvena krivulja) i kombiniranom bruto masom od 44 tone i dvoosovinskim traktorom (plava krivulja)

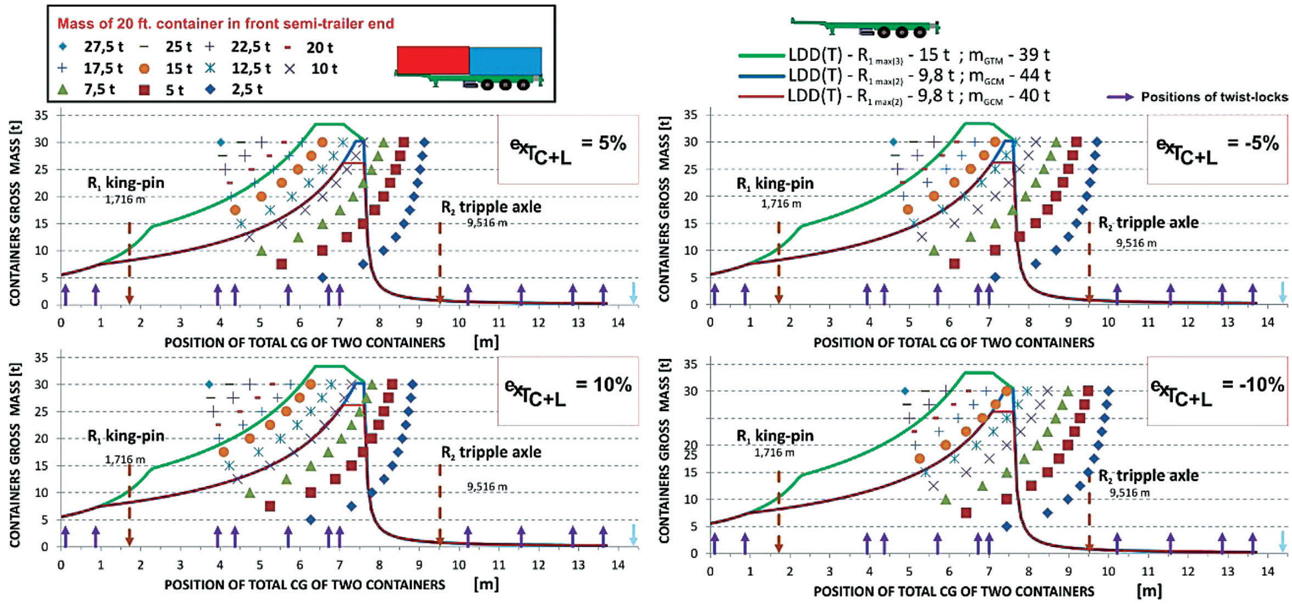

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Figure 4 Positions of total CG of two 20' containers with different gross masses and different eccentricities of container CG

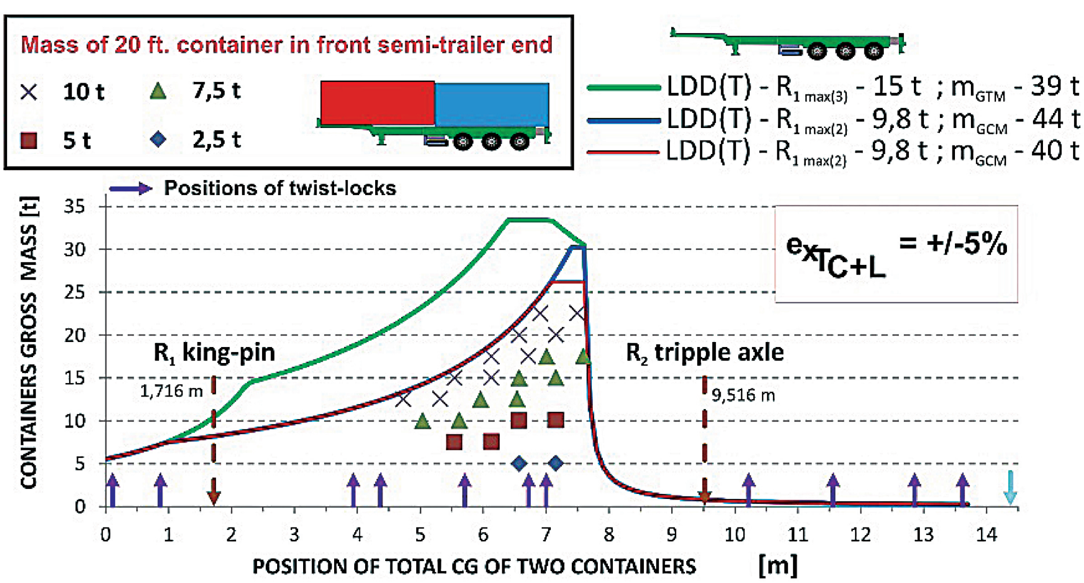
Slika 4. Pozicije svih centara gravitacije dva 20 stopna kontejnera s različitim bruto masama i ekscentricitetima centra gravitacije kontejnera

Some countries (e.g. Slovakia, Hungary) allow also the transport of other intermodal transport units by vehicle combinations up to 44 tonnes.

The maximum cargo mass that can be loaded in container carried by road depends on maximum allowed gross vehicle/combination mass, vehicle/combination tare and container tare. The maximum cargo mass that can be loaded in 40' general purpose container (42G1) and 40' general purpose high-cube container (45G1) carried on road vehicle is given in Table 4. The data were acquired by weighing of 400 containers carried by 60 different vehicle combinations.

When loading a road vehicle the vehicle payload shall be followed with regard to vehicle, trailer (mGTM) and a combined (mGCM) gross mass. Maximum axle loads and minimum loads for steering and driving axles must be followed. Maximum load on semi-trailer king-pin depends on the trailer and the tractor used.

Permissible load on king-pin determines if it is necessary to use two-axle or three-axle tractor. When maximum allowed mass of 18 t for two axle tractor is used, this limits permissible load on king-pin to 9,8 t (8,2 t tractor tare supposed). Maximum gross combination masses and maximum semi-trailer gross mass are showed as mGCM, mGTM axis and limits the payload



Source: authors

Figure 5 Positions of total CG of two 20' containers with +/- 5% eccentricity of container CG with different gross masses at mGCM of 40 tonnes

Slika 5. Pozicije svih centara gravitacije dva 20 stopna kontejnera s +/- 5% eksentriciteta centra gravitacije kontejnera s različitim bruto masama pri 40 tona mGCM of container trailer. For example on Figure 3 maximum container gross mass for five axle (2+3) vehicle combination is 26,2 tonnes for mGCM of 40 tonnes and 30,2 tonnes for mGCM of 44 tonnes.

ANALYSIS OF LOAD DISTRIBUTION OF TWO 20' CONTAINERS IN THE LONGITUDINAL AXIS ON EXTENDABLE CONTAINER CHASSIS / *Analiza raspodjele tereta na dva 20 stopna kontejnera po uzdužnoj osi na produžnom podvozju kontejnera*

Extendable container chassis SCHMITZ S.CF GOOSENECK 45' EURO [6] can transport containers with a length of 20'-45' (see Figure 6). Using the load distribution diagrams on Figure 3, it is possible to assess the load distribution of each container with different mass and different position of CG (see sec. 3). Subsequently considered will be a group of two 20' containers with 5% and 10% eccentricity of container CG in such a way that the combination of container gross masses ranges from 2,5 tonnes to 27,5 tonnes so that the total gross mass of two containers does not exceed 30 tonnes.

The Figure 4 shows these loading combinations with +/- 5% and +/- 10% eccentricity of CG of loaded containers. Both containers have the same eccentricity of CG in the direction to the front or to the rear end of the container chassis.

To assess the possible combinations of loading of two 20' containers for mGCM of 40 tonnes the common centre of gravity of loaded containers for selected combination shall not

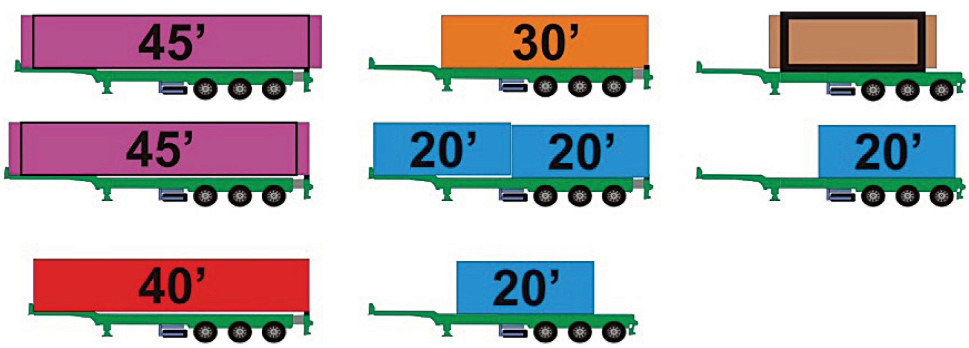
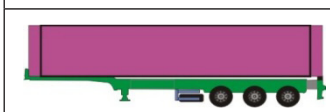
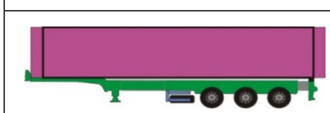
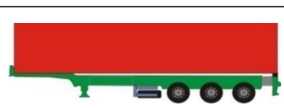
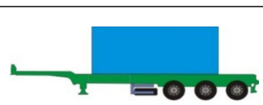
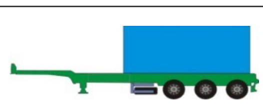
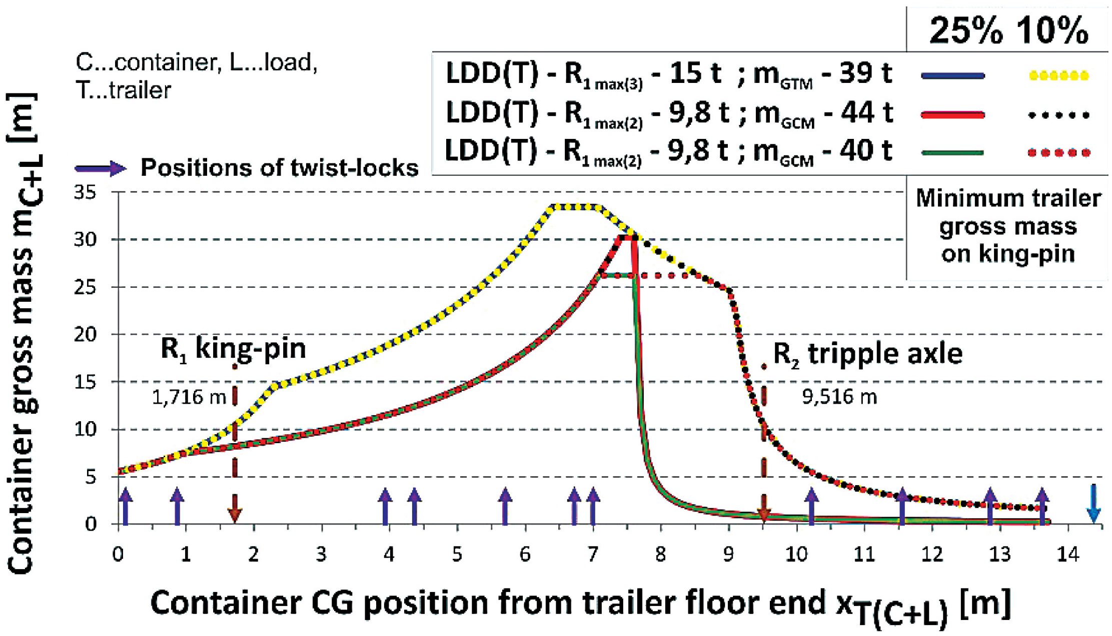


Figure 6 Examples of different containers carried by SCHMITZ S.CF GOOSENECK 45' EURO
Slika 6. Primjeri različitih kontejnera postavljenih na SCHMITZ S.CF GOOSENECK 45' EURO

Table 5 Loading parameters of selected containers for the construction of LDD(T+C)
Tablica 5. Parametri ukrcaja tereta odabranih kontejnera za izgradnju LDD (T+C)

Loading configurations	Container size and type code ISO 6346	Distance of empty container CG from the semi-trailer maximum extended front end x_{T_c} x_{T_c} [m]	Container tare [t]	Container gross mass [t]	Container internal length [m]	Longitudinal distance of corner fittings [m]
	LEG1	6.86	4.25	34	13.542	13.509
	L5G1	7.62	4.8	34	13.542	13.509
	42G1	6.86	4	30.48	12	11.985
	22G1	7.29	2.2	30.48	5.9	5.853
	22G1	8.63	2.2	30.48	5.9	5.853



Source: authors

Figure 7 Comparison of load distribution diagrams of semi-trailer with minimum semi-trailer gross mass on king-pin of 25% and 10% of total semi-trailer gross mass

Slika 7. Usporedba dijagrama raspodjele tereta polu-prikolica s minimalnom bruto masom polu-prikolice od 25% i 10% ukupne bruto mase polu-prikolice.

exceed the red curve.

Figure 5 shows only the selected combinations of 20' containers with +/- 5% eccentricity of CG for this semi-trailer at mGCM of 40 tonnes, where the gross mass of the container in the front end shall be from 2,5 tonnes (empty) to maximum 10 tonnes, otherwise the tractor will be overloaded.

THE ANALYSIS OF LOAD DISTRIBUTION OF DIFFERENT TYPES OF CONTAINERS CARRIED BY EXTENDABLE SEMI-TRAILER CONTAINER CHASSIS / *Analiza raspodjele tereta kod različitih tipova kontejnera na podvozjima produžnih polu-prikolica*

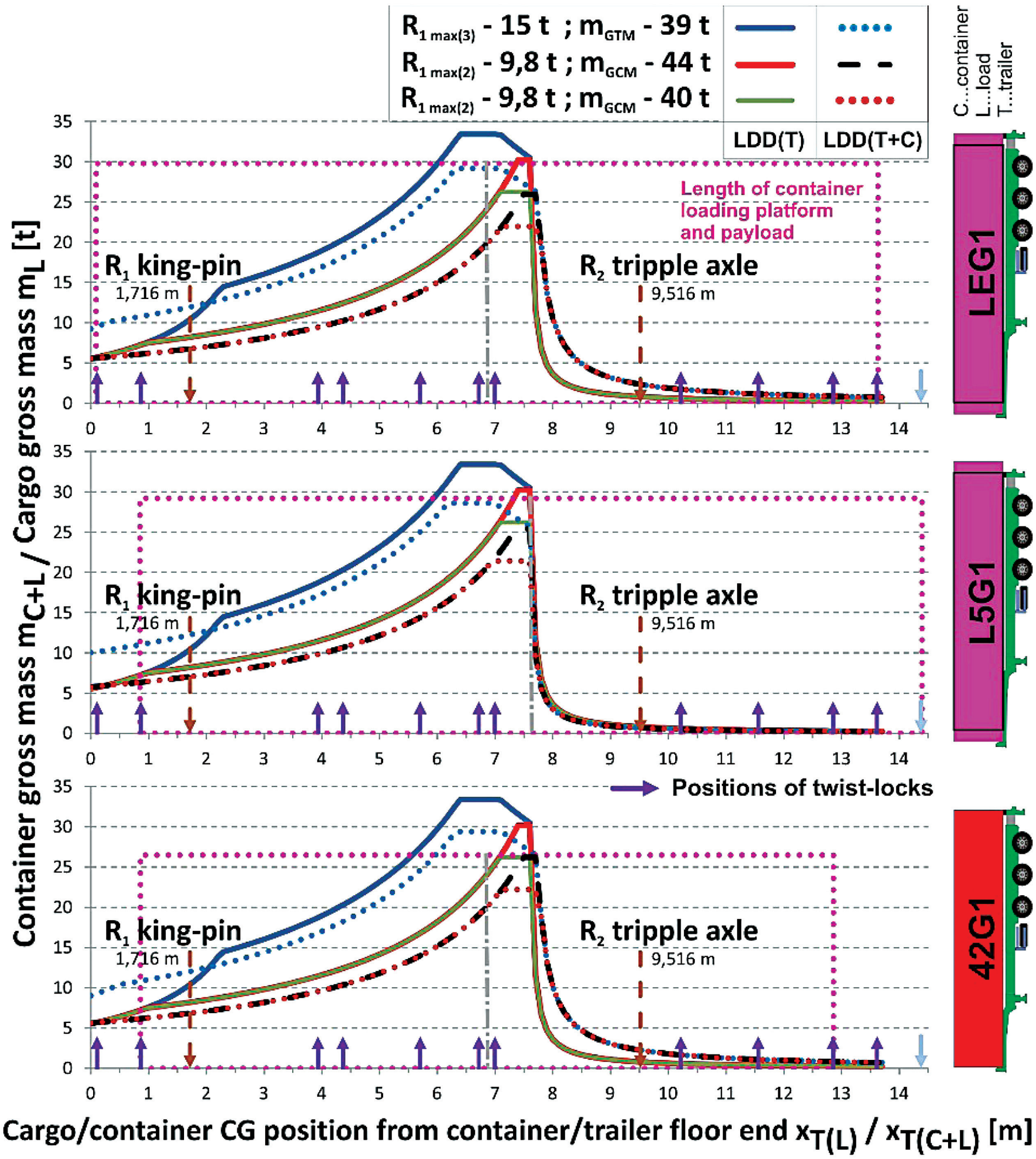
The intermodal load distribution diagram of the container loaded on container chassis LDD(T+C) can be constructed taking into account the requirements defined in section 2 of this paper. The resulting load distribution diagram uses container tare, which presents also the load for the trailer. Examples of different containers that can be carried by selected container chassis are showed on Figure 6 and loading parameters are given in Table 5.

Load distribution diagrams of the vehicle with empty container LDD(T+C) can be combined with load distribution diagram of the container LDD(C) thus creating intermodal load distribution diagram container-vehicle. However, this is only possible if only one container is loaded on container chassis. Load distribution of two containers was analysed in section 2.3 of this paper. Minimum 25% of trailer gross mass is assumed on king-pin which is suitable for 45', 40' and 20' container in the middle but when 20' container is loaded at the rear end than this boundary is too high. Comparison of load distribution diagrams of semi-trailer LDD(T) when minimum trailer gross mass on king-pin is 25% and 10% is on Figure 7. If we require only 10% of the trailer gross mass on king-pin, then the container CG can be located more to the chassis rear end.

Using diagrams LDD(T), we can assess correct loading of loaded container with a certain mass and certain position of CG of loaded container. Using diagrams LDD(T+C), we can assess correct loading of cargo of certain mass and certain position of cargo CG in container when loaded on container chassis. But when also eccentricity of CG of loaded container shall be verified than diagrams LDD(T+C) shall be combined with the diagrams of LDD(C) showed on Figure 1.

For 45' continental container LEG1 and maritime container L5G1 almost the whole payload can be used for cargo but only when three-axle tractor, semi-trailer gross mass of 39 tonnes and gross combination mass of 44 tonnes for combine transport is used. LEG1 container is placed directly in the middle of container chassis so positive and negative eccentricity of container CG can be used. However, the loading of L5G1 container assumes container CG in front half and not in rear half of loading platform. Container 42G1 is loaded also in the middle of container chassis so the situation is similar to LEG1. This example shows that such container chassis are designed for the use of three-axle tractors but this is not possible in each country because of low maximum allowed gross combination mass and related economic costs.

When using two-axle tractor and gross combination mass of 40 tonnes only 22 tonnes of cargo can be loaded into these containers. Cargo CG must be close to the middle in container rear half for LEG1 and 42G1 containers and in front half for L5G1 container or when minimum trailer gross mass on king-pin is 10% of semi-trailer gross mass (see Figure 7) than for L5G1 container cargo CG can also be in rear half close to the middle. When carrying 20 'container loaded in the middle of container chassis 24 tonnes of cargo can be loaded at gross combination mass 40 tonnes and 28 tonnes of cargo at mGCM of 44 tonnes with the cargo CG eccentricity close to the middle when 25% of semi-trailer gross mass is supposed on king-pin as minimum. If only 10% is supposed than 20' container can be



Source: authors

Figure 8 Comparison of load distribution diagrams of container chassis LDD(T) and container chassis with empty containers LDD(T+C) for containers LEG1, L5G1 and 42G1

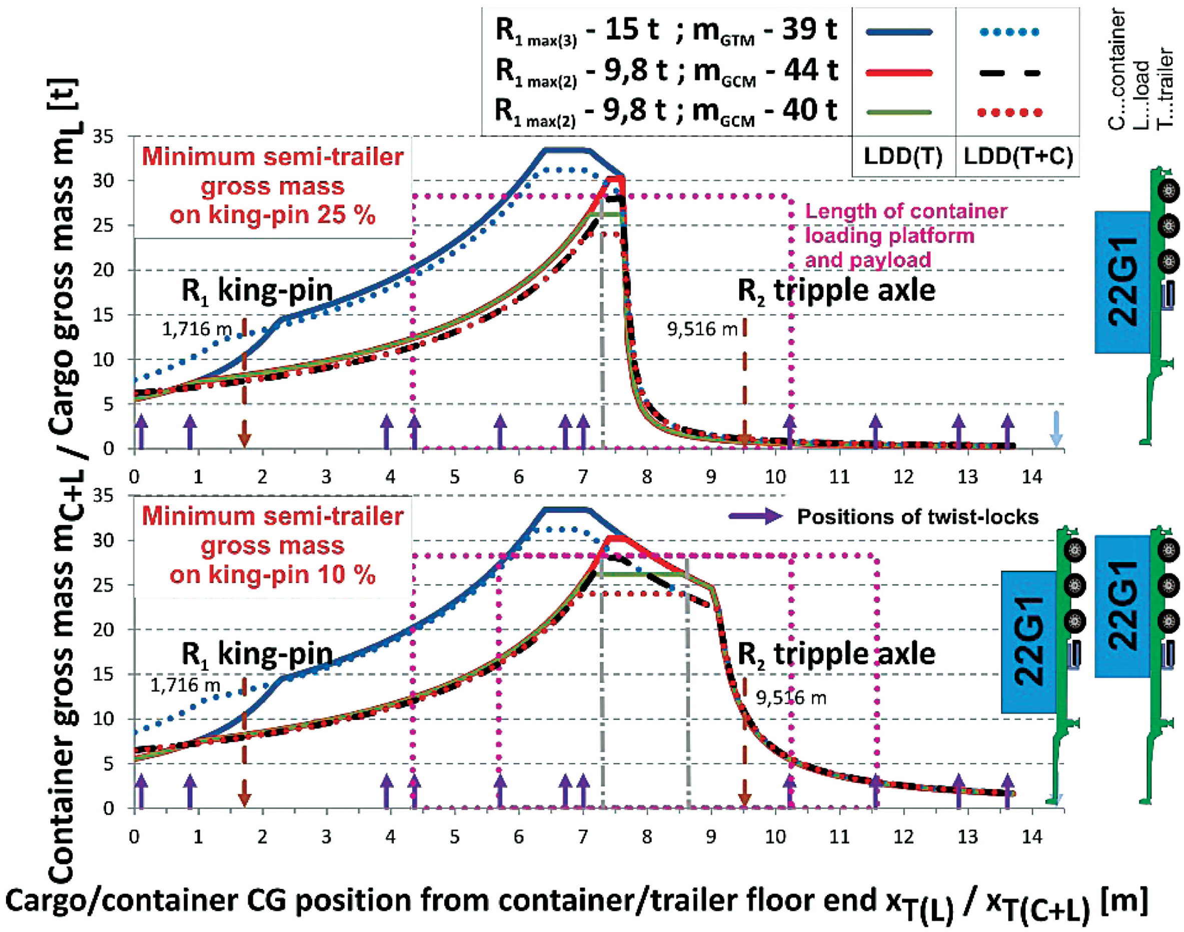
Slika 8. Usporedba dijagrama raspodjele tereta podvozja kontejnera LDD(T) i podvozja s praznim kontejnerima LDD(T+C) za kontejnere LEG1, L5G1 i 42G1

loaded in the middle and also at rear end of container chassis. However, when loaded in the middle of container chassis than cargo CG eccentricity is more suitable in container rear half and when loaded at the rear end than in the container front half. When 20' container is loaded at rear end then only 24 tonnes of cargo is possible to load even at mGCM of 44 tonnes because of maximum allowed mass on triple axle. For container chassis where maximum allowed mass on triple axle is 24 tonnes instead of 27 tonnes than only 21 tonnes of cargo can be loaded in 20' container loaded at the rear end of container chassis. This example is very important to note because of position of 20' container at the rear end even mGCM of 40 tonnes is not possible to use but only 37 tonnes.

INTERMODAL LOAD DISTRIBUTION DIAGRAM OF 40FT CONTAINER CARRIED ON CONTAINER CHASSIS / *Dijagram intermodalne raspodjele tereta 40 stopnih kontejnera na podvozju*

After the composition of the LDD(T+C) diagrams with LDD(C) diagrams allowed areas of cargo CG are showed in relation to the correct loading of container and container chassis. As an example of such a composition 40' container 42G1 is used and the diagrams are showed on Figure 9.

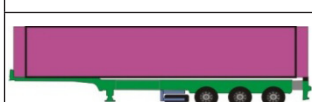
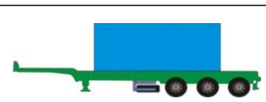
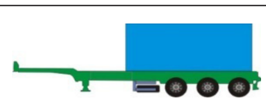
When container LDD(C) and chassis LDD(T+C)'s are



Source: authors

Figure 9 Composition of load distribution diagrams of 40' container LDD(C) with LDD(T+C)
Slika 9. Struktura dijagrama raspodjele tereta 40 stopnih kontejnera LDD(C) s LDD (T+C)

Table 6 Maximum cargo mass in different containers loaded on container chassis (tare 13.8 tonnes)
Tablica 6. Maksimalna masa tereta različitih kontejnera postavljenih na podvozje kontejnera (masa 13,8 tona)

Loading configurations	Container size and type code ISO 6346	maximum cargo mass in container	
		m_{GCM} 40 tonnes	m_{GCM} 44 tonnes
	LEG1	21,95	25,95
	L5G1	21,40	25,40
	42G1	22,20	26,20
	22G1	24,00	28,00
	22G1	24,00	24,00 21,00*

* if maximum allowed mass on triple axle is 24 tonnes

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 favourable for gross combination mass 40 t but for 44 t there is not big difference. When the cargo CG is in front container half than the tractor is overloaded.

With increasing the mass, the position of CG must move towards container doors up to maximum cargo mass of 22 tonnes for mGCM of 40 tonnes. If gross combination mass of 44 tones is used than maximum cargo mass can be 26 tonnes but with cargo CG is on the boundary of 5 % eccentricity of container CG.

CONCLUSION / *Zaključak*

Based on the selected container chassis we can conclude for such type of vehicles that the type of container and position of container influence the maximum cargo mass in container. The maximum cargo mass in container for 20', 40' and 45' general purpose containers and selected container chassis varies from 21,4 to 28 tonnes.

When 20' container is loaded at rear end then only 24 tonnes of cargo can be loaded even at mGCM of 44 tonnes because of maximum allowed mass on triple axle. For container chassis where maximum allowed mass on triple axle is 24 tonnes instead of 27 tonnes than only 21 tonnes of cargo can be loaded in 20′ container loaded at the rear end of container chassis. This example is very important to note because of position of 20′ container at the rear end even mGCM of 40 tonnes is not possible to use but only 37 tonnes.

Analysed examples showed that such extendable 45′ container chassis are designed for the use of three-axle tractors but this is not possible in each country because of low maximum allowed gross combination mass and related economic costs.

Correct loading of containers can be performed with the use of load distribution diagram to know the position of cargo CG not to overload or overweighed handling equipment and road vehicles. When constructing intermodal load distribution diagrams, than each container chassis shall have such number of diagrams regarding how many loading configurations of different containers can be carried on the chassis.

These diagrams help to define the position of cargo CG for each loading configuration. This is quite different to regular vehicles with platform or box type body where only one set of diagrams is sufficient. The procedure how to combine load distribution diagrams of different cargo transport units and their combinations is universal and can be used also for swap bodies and railway wagons but only when one cargo transport unit is carried by another cargo transport unit. When more cargo transport units are carried by another cargo transport units than common CG shall be calculated and compared with load distribution diagrams of carrying cargo transport unit. Construction of load distribution diagrams or calculation of axle loads for container vehicles helps designers to verify each container loading configuration which means that the vehicles are more suitable to carry different types of containers in term of their mass and centre of gravity not only in term of their length. The procedure of calculation of load distribution can be a part of telematics applications to increase the transport safety. According to Kalasova et. al. [1], safety is emerging as an area of increased concerns, attention and awareness within the transportation engineering.

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