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MODELING OF TRUCK LOADING

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Abstract. In the logistics chain the largest number of commodities is still transported by road using trucks coupled to semi-trailers (tractor-trailers). One of the most important aspects is safe loading and transportation of cargo. This article focusses on the issue relevant to May 20th, 2018. From that date the rules for the layout and securing of commodities carried by road vehicles are no longer valid in Lithuania (https://www.iru.org/sites/default/files/2020-11/en-safe-load-guidelines.pdf, Directive 96/53EC.). There are no new rules so the article provides recommendations for safely loading a three-axle semi-trailer. From the scientific perspective it must be concluded that trucks coupled to semi-trailers may only be loaded up to the maximum permissible capacity only in the case if the overall centre of gravity of the commodities is located in a certain given area. However, even if the weight of the commodities is below the maximum, they must be stowed only in certain areas. Otherwise, the axle load may be too high or too low. However, even when the weight of the commodities does not reach the maximum lifting capacity, they must be stacked only in certain areas of the area allotted to them. Otherwise, the axle load may be too high or too low. Otherwise, the axle load may be too high or too low. Using the load distribution curve, the load distribution diagram can be used to determine the distance from the front wall and the weight of the semi-trailer. In the paper, the loads of semi-trailers are modeled with the help of the software "Truck Science-bodybuilder" and load distribution curves are created for a three-axle semi-trailer model.

Keywords: three-axle semi-trailer, modeling, semi-trailer load curves.

INTRODUCTION

The center of gravity of heavy-duty vehicles-tractors is very important for increasing driving efficiency, truck stability on the road, distribution of braking forces. If the commodities are not loaded according to the instructions, for example, the heavy ones are loaded at the rear of the semi-trailer, then the drive axle of the truck (tractor) have no good grip on the ground the drive wheels may not even reach the ground in the case or the grip will be very poor. If heavy commodities are placed in front of the semi-trailer, there will be overweight on the drive axle, which will affect the adhesion of the front axle of the truck (tractor). So the loading is the basis for safe operation of the tractor.

The load distribution curves in the semi-trailer can help to determine the exact position of the commodities during loading. European semi-trailer manufacturers provide recommended load distribution curves. An example of such a curve is given in Figure 1. This diagram only allows to determine an approximate orientation of loading a semi-trailer: it can be used to find out only where the heaviest commodity should be placed. The graph shows that it is recommended to load commodities (cargo) up to 7 t at the front of the semi-trailer, up to 30 t - in the middle and up to 2-3 t at the very rear.

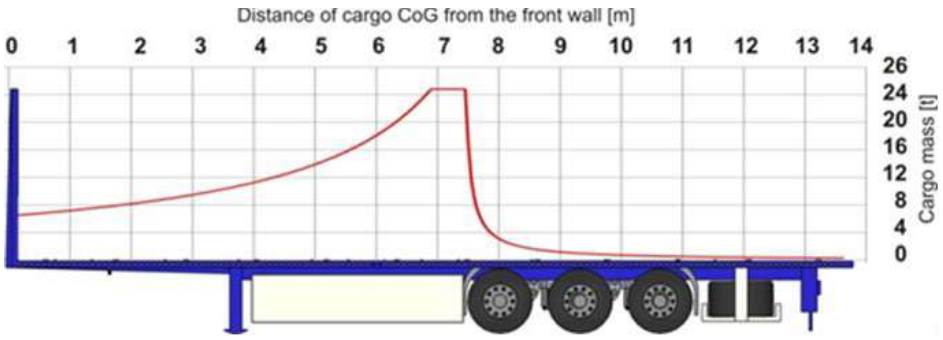

Figure1. **Example of cargo distribution diagram - semi-trailer** (Aliyu et al., 2015*)*

So the objective of the paper – present the modelling results of truck loading. The tasks of the paper: present models the loading cases of various loads and createsload distribution curves for a three axle semi-trailer model.

MODELING THE POSITION OF TRUCK'S AND SEMI- TRAILER'S CENTER OF GRAVITY

Truck stability and operational safety depend on the effects of inertial forces (Cekałaet et al., 2015). The forces of inertia are concentrated at the point of center of gravity (Choong-Yeunet et al., 2009*)*. The position of the center of gravity depends on the dimensions of the load and the position on the semi-trailer. The paper presents a simulation of the dynamic center of gravity displacement when the commodities are withdrawn from the front wall by one meter. An example of gravity center calculation scheme of is given in Figure 2. The modeling assumes that: cargo dimensions 2.4 m x 4.0 m; the dynamic center of gravity of the cargo is the point of intersection of the load with the axes of rectangular symmetry the hight of the cargo always the same.

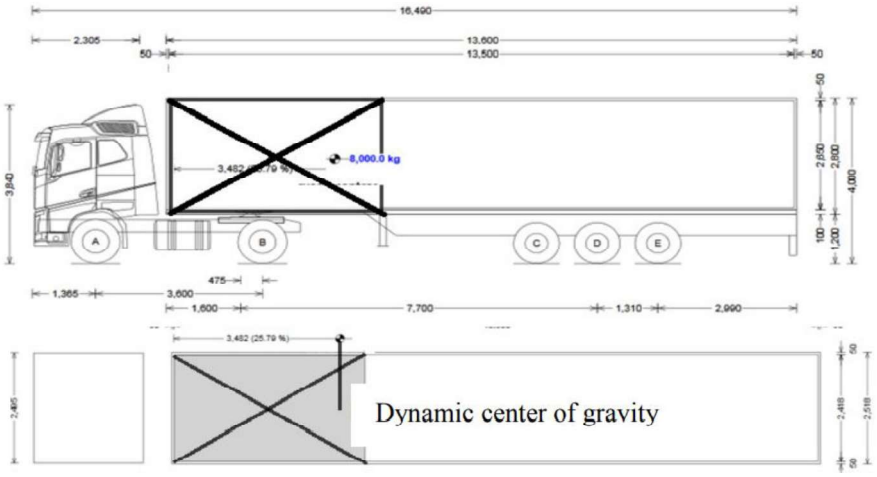

Figure2. **Example of a scheme for determining the dynamic center of gravity of a two-axle truck and a three-axle semi-trailer with a load dimension of 2.4x4 m and a mass of 8 t.**

Two-axle and three-axle truck and three-axle semi-trailer models were developed with the Truckscience software package. The results are presented in Fig. 3 and 4. Model data: cargo masses – 8000 kg and 17000 kg, cargo length – 4m, cargo width – 2.4 m, height is not evaluated, it was assumed that the center of gravity of the cargo is at the intersection of its diagonals, i. e. in the center. Total weight of the truckand semi-trailer was *m= 151704 kg.*

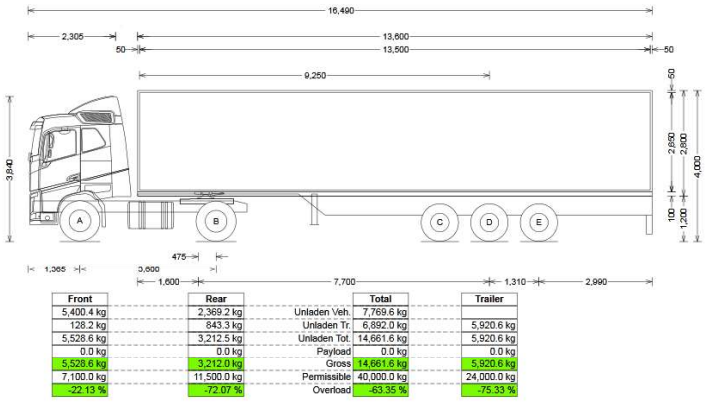

Figure 3. **Two-axle truck and three-axle semi-trailer model in „Truckscience"**

After all, during the simulation, cargo of 8000 kg and 17000 kg were moved from the front wall of the semi-trailer to the end. Dynamic center of gravity displacement was calculated for both two-axle truck and three-axle semi-trailer and three-axle truck and three-axle semi-trailer models. The center of gravity change curves are shown in Figures 5 and 6.

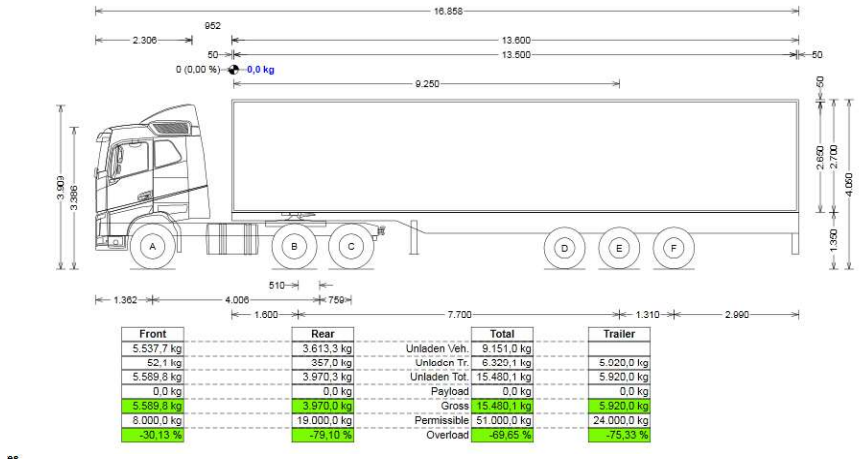

Figure 4. **Thre-axle truck and three-axle semi-trailer model in „Truckscience“**

From the diagrams a regularity was established: they demostrate how the dynamic center of gravity shifts for both the two-axle tractor and the three-axle semi-trailer model and the three-axle tractor and the three-axle semi-trailer model. The diagrams (Figure 5 and Figure 6) show that the displacement of the dynamic center of gravity increases steadily and slides towards the end of the semi-trailer. The model of the two-axle tractor and the three-axle semi-trailer showed that, when both 8000 and 17000 kg cargos were pushed 2.8 m from the front wall, the dynamic center of gravity of the combination overlapped. In the three-axle tractor and three-axle semi-trailer model, the dynamic center of gravity coincides with the load displacement 2.6 m from the front wall of the semi-trailer.

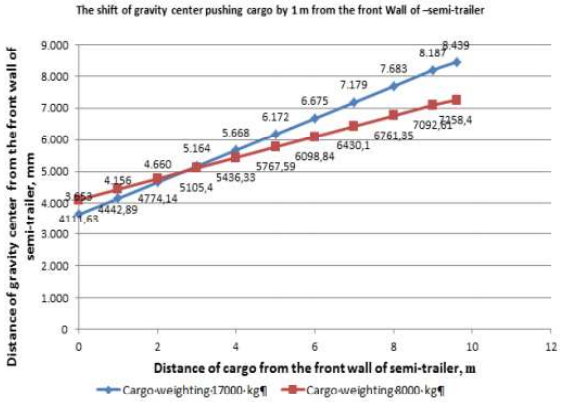

Figure 5. **Dependence of the dynamic center of gravity of a two - axle truck and a three - axle semi - trailer if the cargo weight accordingly 8000 and 17000 kg.**

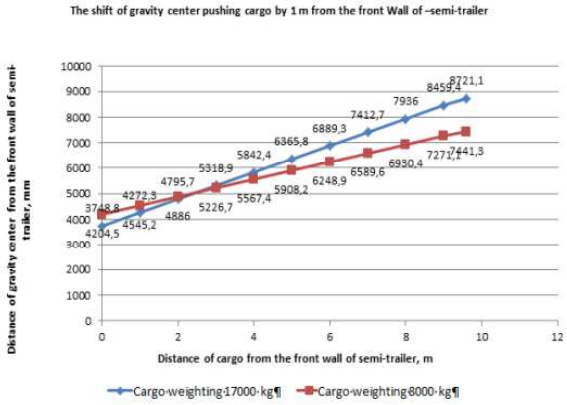

Figure 6. **Dependence of the dynamic center of gravity of a three - axle truck and a three - axle semi - trailer if the cargo weight accordingly 8000 and 17000 kg.**

COMPILATION OF A LOAD DIAGRAM FOR A THREE-AXLE SEMI-TRAILER: RESULTS

Using the modeling software package Truckscience, it was determined what the maximum weight of a cargo could be when its width is 2.4 m and its length varies (Savaidis et al., 2013; Aliyu et al., 2015).

By pushing the cargo from the front of the semi-trailer towards the end, it was determined what the maximum weight of the cargo could be and at any part of the semi-trailer, within the permissible axle loads. The length of the cargo was increased every 1 m. The maximum permissible axle loads for the tractor and semi-trailer have been set. Chart that allows to determine the exact location of the cargo in semi-trailer was received. A three-axle semi-trailer load diagram is presented in Figure 7. This diagram is significantly more accurate than the manufacturer's recommended three-axle semi-trailer load diagrams.

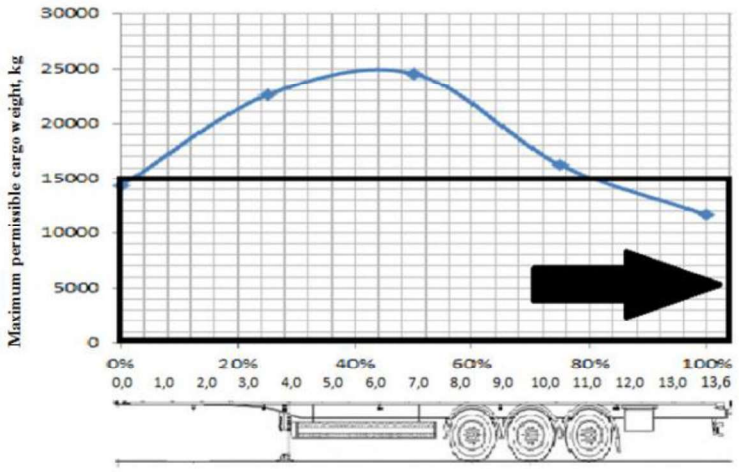

Figure 7. **Scheme of 13,6 m. long cargo on three axle semi- trailer**

CONCLUSIONS

1. The modelling results have shown that the center of gravity slides smoothly from the front of the semi-trailer towards the rear what means, that when the cargo is loaded at the rear of the semi-trailer, the center of gravity is furthest from the front wall.

2. The axle loads change steadily as cargo is pushed from the front wall of the semi-trailer towards the rear, the non-driving and driving axle loads decrease steadily, and the axle load of the semi-trailer increases steadily.

3. Pushing cargo weighing 8000 kg loaded on a two-axle tractor with a three-axle semi-trailer, the permissible axle loads are not exceeded, but pushing a load weighing 17000 kg on the driving axle of a two-axle tractor when the load is pushed from 0 m to 3m from the front wall the axles of the semi-trailer are overloaded when the load is moved more than 8 m from the front wall of the semi-trailer.

4. When a cargo of 8000 kg is loaded on a three-axle tractor with a three-axle semi-trailer, the permissible axle loads are not exceeded, but when the load weighs 17000 kg and is pushed from the front of the semi-trailer towards the end of the semi-trailer, the semi-trailer axle load is exceeded.

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