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Studies and research regarding optimal cargo load of a transport van using carmaker software

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Abstract. The main objective of this paper is to find the optimal positioning of a cargo load in a given van, using simulations implemented in CarMaker. The chosen cargo weight is 1000 kg (close to the limit of the chosen van, 1350 kg), and the factors that are used as input are: the type of driver (aggressive, defensive and normal – for each type of driver the longitudinal acceleration and decelerations vary and also the maximum velocity and lateral), the road that was kept the same and was built so that the driver has to follow several curves left and then to the right with decreasing curve radius, the manoeuvres are set as a maximum speed on the given road (100 km/h, adapted by the driver so that the van stays on the road), and the tires were kept the same. The 1-ton load was placed in the van in 9 points on two planes with different heights and all the simulations were compared to the unloaded van. Also, an 80-kg driver was input. The results that were exported from all the simulations were: the total damp force of all the wheels, the yaw angle, the pitch angle, the roll angle, the yaw rate (measured in degrees/second), the pitch rate and the roll rate all correlated to the velocity of the vehicle. CarMaker offers a lot of output information regarding the vehicle behaviour due to the complexity of the equations behind the software. Another advantage is the coupling possibility with AVL InMotion so that the virtual engine is replaced with the real engine coupled to the DynoRoad dynamometer in the Testing and Homologation Laboratory of the Automotive Engineering and Transport Department (Technical University of Cluj-Napoca). To ensure the uniformity of the forces that occur while driving on a road with curves, in all the elements of the suspension system, the load must be placed in the centre area of the van. However, the idea of the simulations was the lack of side doors of some vans that require an un-cantered placement of the cargo.

1. Introduction

In early studies, researchers like Heidelberg et. al. [1] and BostelMan et. al. [2] were interested more in the way of loading and placement of cargo during the manufacturing or for Naval Research.

In more recent researches, automation has taken over the loading of the cargo, so the research has gone towards that direction, like Teller et. al. [3], studied a voice-comandable robotic forklift working alongside humans in minimally-prepared outdoor environments; McLaughlin et. al. [4] researched a detector placement optimization for cargo containers using deterministic adjoint transport examination for SNM detection; while Turanov et. al. did an analytical investigation of cargo displacement during the movement of rolling stock on a curved section of a track. Further researches underlined the development of a decision support system for air-cargo pallets loading problem and also problems regarding analytical modelling cargoes displacement in wagon and tension in fastening, researches made by Chan et. al. [6] and Turanov et. al. [7]. Also Kothawade et. al. [8] and Patil et. al. underlined the importance of space optimization methodologies, the trend being toward automation, like shown by Kim et. al. Modern methods allow the user to simulate the effect of the cargo with consideration to the vehicle aerodynamics, the driver (the aggressivity of the driver), the influence of the road, maneuvers, and more importantly the effect of the cargo placement on the vehicle suspension durability, by monitoring the angles of the vehicle and the rate (Figure 1).

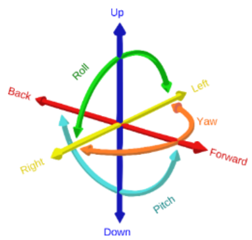

Figure 1. Monitored vehicle angles

2. Methodology

Using the AVL InMotion system, and its CarMaker software, a simulation was done, to research the influence of the placement of the cargo on the angles of the vehicle and the rate (yaw rate, pitch rate and roll rate) because they influence the ware of the suspension system directly.

The input data of the simulation are: the vehicle was chosen, a Mercedes van with back loading possibility only and a maximum load capacity of 1300kg (in the simulation, the cargo load was considered 1000kg and the 80 kg driver, like shown in Figure 2); the vehicle body and aerodynamics are presented in figure 3; the road was implemented in CarMaker by using segments, a straight line so that the vehicle can get up to 100 km/h, and then a series of left and right curves with decreasing radius like shown in figure 4; the driver was set to normal, with an allowed acceleration of 3 m/s, lateral acceleration of 4 m/s and a deceleration of -4 m/s; the imposed maneuvers were 100 km/h speed with a manual gear shifting by the smart driver.

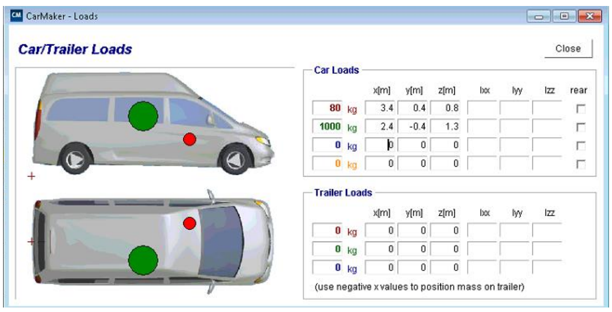

Figure 2. Chosen vehicle and loads

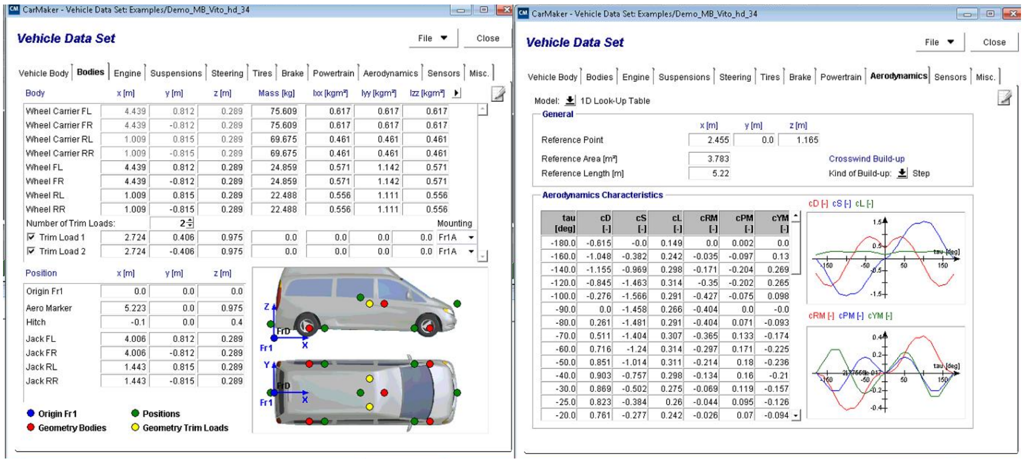

Figure 3. Vehicle bodies and aerodynamics

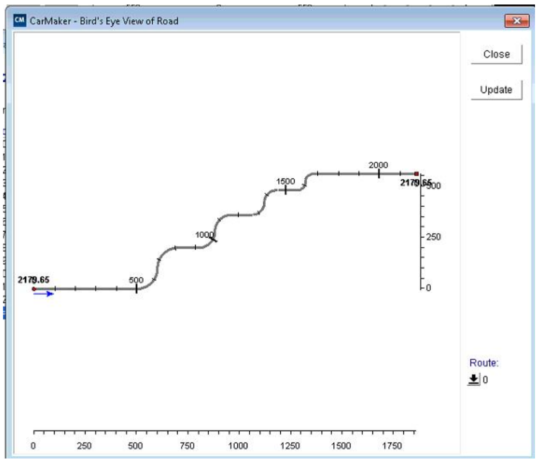

Figure 4. Implemented road in CarMaker

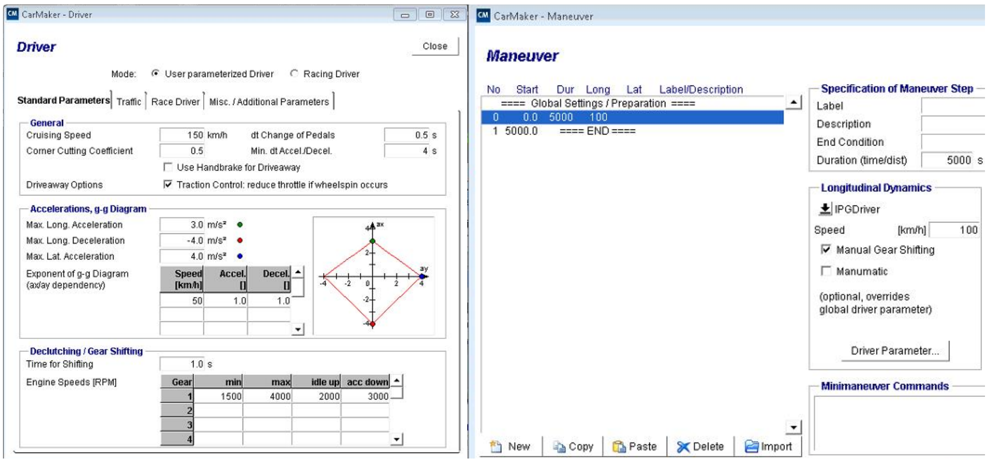

Figure 5. Driver and maneuvers in CarMaker

The cargo placement strategies are presented in figure 6. Two planes were chosen, the upper plane at 1.3m and the lower at 0.8m (on the floor of the van) and three sections: the central section, the left section (placed at -0.4m) and the right section at 0.4m.

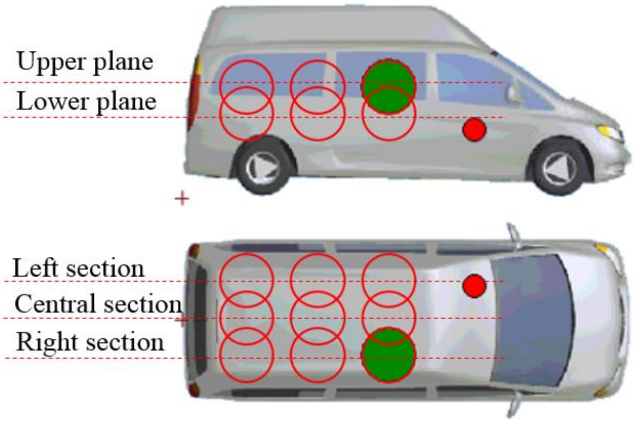

Figure. 6. Cargo placement strategies

Table 1. Study cases and the notation.

Case number	Placement of the cargo (x,y,z coordinate) [m]	Case number	Placement of the cargo (x,y,z coordinate) [m]
1	**No load**	11	1.7 0 1.3
2	1.7 0 0.8	12	2.4 0 1.3
3	2.4 0 0.8	13	1 0 1.3
4	1 0 0.8	14	1 0.4 1.3
5	1 0.4 0.8	15	1 -0.4 1.3
6	1 -0.4 0.8	16	1.7 0.4 1.3
7	1.7 0.4 0.8	17	1.7 -0.4 1.3
8	1.7 -0.4 0.8	18	2.4 0.4 1.3
9	2.4 0.4 0.8	19	2.4 -0.4 1.3
10	2.4 -0.4 0.8		

3. Research and results

The first set of results that were extracted are presented in Figures 7 and 8: the Total damp friction force for all 4 wheels, for case (1) and (15) respectively.

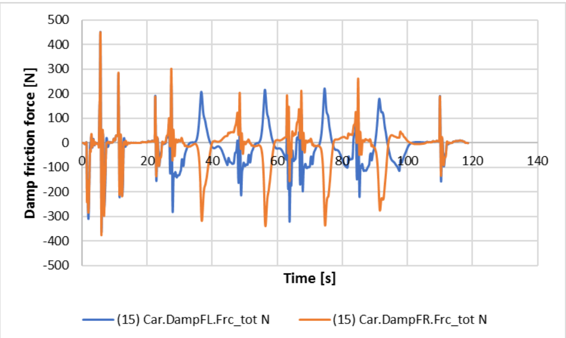

Figure 7. Total damp friction force for front wheels for case (15)

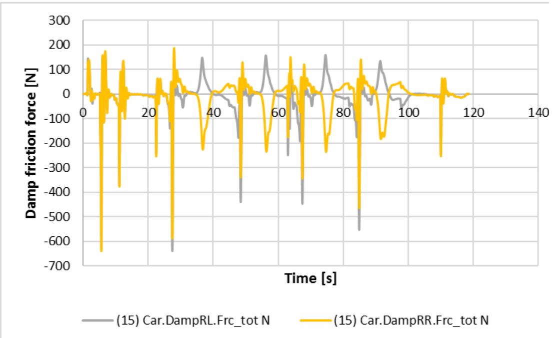

Figure 8. Total damp friction force for rear wheels for case (15)

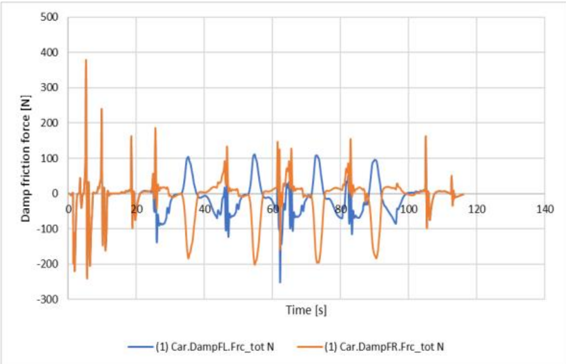

Figure 9. Total damp friction force for front wheels for case (1)

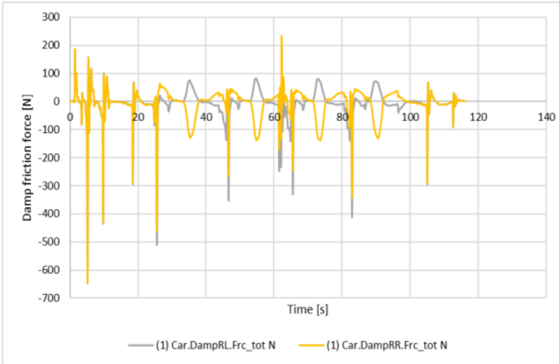

Figure 10. Total damp friction force for rear wheels for case (15)

The most significant cases to compare are (1), (2), (9) and (15) because (1) is unloaded, (2) is a central low placed cargo, while (9) is a front right low placed cargo and (15) is a back left high cargo.

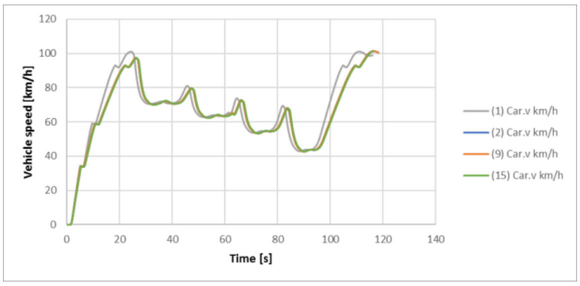

Figure 11. Vehicle velocity variation for cases (1), (2), (9) and (15)

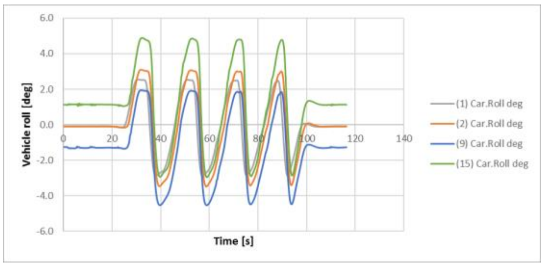

Figure 12. Vehicle roll angle variation for cases (1), (2), (9) and (15)

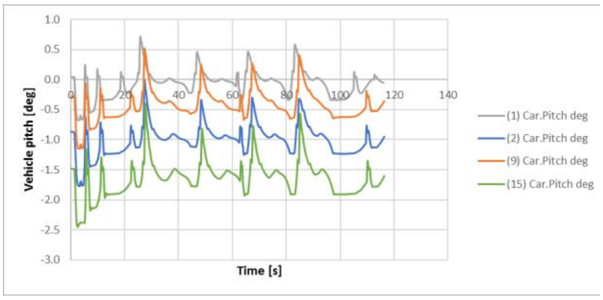

Figure 13. Vehicle pitch angle variation for cases (1), (2), (9) and (15)

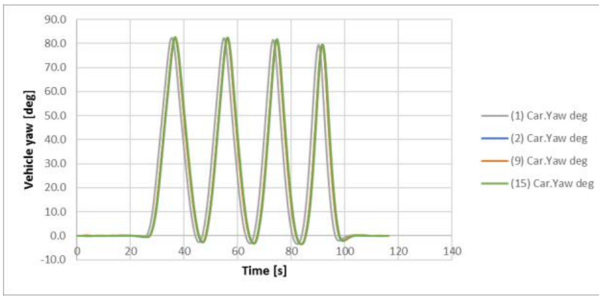

Figure 14. Vehicle pitch angle variation for cases (1), (2), (9) and (15)

4. Conclusions

AVL InMotion is a complex system that allows the user to insert data for simulation, while one of the components is real instead of virtual, making it a Hardware in the Loop simulation/test. That would be the next step of the current research.

For the current simulations, it can be observed that the Total damp friction force has a similar variation in both cases (1) and (15), but due to the 1-ton load on case (15), the Total damp friction force on the Front Right wheel is bigger, from 380 N to 440 N for case (15). For the Left wheels the variation is similar, but for case (15) the Total damp friction force doubles from 100 N to 210 N and the variation is more aggressive (has a peak).

Despite the different placement of the cargo, the velocity of the vehicle can be maintained the same by the smart driver, that is why only a variation between cases (1) and (2) can be observed.

Variations for cases (2), (9) and (15) overlap. Due to the cargo weigh, the vehicle cannot reach the desired velocity (100 km/h) because the vehicle must take the first curve.

The vehicle roll angle variation was presented, and the conclusions are: the highest vehicle roll of 5 degrees is for case (15) because of the high placement of the cargo, while for a central low positioning (case (2)), the angle does not vary only with 0.6 degrees from the unloaded van (1). By placing the cargo on the right like in case (9), the vehicle roll angle will be bigger on the negative side, but about the same as in case (15).

The influence of the cargo placement can be observed also in the vehicle pitch angle variation. The smallest pitch of the vehicle is achieved for the empty van case (1). For case (9), because the cargo is placed close to the center of gravity of the van, the pitch varies from -1.2 to 0.5 degrees, followed by larger variations for cases (2) (from -1.7 to 0degrees) and (15) (from -2.49 to -0.4 degrees).

The vehicle pitch angle has an overlap for cases (2), (9) and (15) due to the added cargo, and the placement does not influence it, only in comparison to case (1).

As a general conclusion, the optimal placement of the cargo is low, as close as possible to the center of gravity of the vehicle and centered to the vehicle axis. Even though if placed on the left or right, the roll angle can be corrected by the driver, but the vehicle velocity will be directly influenced.

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