Investigation of the influence of “Roadtrain” and “Truck speed 100 km/h” on handling characteristic, fuel consumption and traffic flow

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1 Introduction

In the freight traffic the importance of trucks grows constantly. Between 1991 and 1997 the transportation performance of the long distance goods traffic with commercial vehicles increased by nearly 30 % [VER98]. The forecast for the freight transportation expects an increase of the transportation performance by 55 % until the year 2015 [ADA99]. Based on today’s transportation regulations, this improvement would cause a direct increase of the kilometrage with a higher traffic load. One possibility to avoid this effect is to extend the vehicle load in freight transportation.

In most European countries the vehicle load in today’s traffic is limited to a maximum weight of 40 t with a maximum vehicle length of 18.75 m. This enables to carry for example two C 782 containers with a possible load capacity of 25 t. Based on these regulations there are a lot of solutions existing, that try to maximize the transportation capacity. To achieve a significant improvement for higher demands of the future, a new approach is necessary, where the maximum weight and length are enlarged, taking into account the road limitations. To avoid road damages, the maximum load per axle of today has to be kept constant. In addition the vehicle safety must be ensured as well as the drivability in the traffic flow. Vehicle technologies like air suspension, disc braking, retarders, electronic stability program or active steering can be used to guarantee all requirements. This leads to the concept of roadtrains. Outside of Europe, roadtrains are already existing. In Australia for example long lorry combinations of up to 50 m in length are common, but the technological level of them is not useful here (Fig. 1-1).

Fig. 1-1: Roadtrain (Australia, 1997) [KAS98]

These roadtrains are not self-tracking and as a result their roadholding properties are far from ideal for use in densely populated European countries. For example German legislation demands a cornering ability defined by § 32d StVZO. This causes the need for a new roadtrain concept.

Another basic approach to improve traffic flow with a high freight transportation rate is to increase speed limit for trucks up to 100 km/h. The maximum speed for trucks in Germany is limited to 80 km/h. The passenger cars are allowed to go much faster. So especially on two lane highways a high speed difference arises between the two lanes. This situation often leads to high traffic loads and local collapses of traffic flow if for example a truck changes to the left lane. Trucks of the newest generation offer the chance to drive at higher speeds, because the modern technology of drive train, brake system and chassis is able to manage the demands of a roadtrain at 100 km/h.

The Institut fuer Kraftfahrwesen Aachen der RWTH Aachen (ika) analysed the influence of roadtrain-concepts and speed limit 100 km/h for trucks on traffic flow, fuel consumption and handling characteristics.

2 Cornering ability and handling characteristics

The analysis of lateral dynamics was done using the multi body simulation tools ADAMS and SIMPACK. To examine the handling characteristics of the truck a model was employed, which was validated in trials on a testing ground. This standard truck-trailer was extended with a coupling tow-bar and a second trailer. The first simulations were done with the models of two standard trailers (Fig. 2-1). Starting from this point different concepts of additional steering axles were examined to improve the cornering ability of the roadtrain [SAN98]. The goal was to live up to the demands of German "BO-Kraftkreis" (§32 d StVZO). For the investigation of the cornering ability the steering axle concepts steering trailing axle, steering stub axle and fifth-wheel steering axle were employed. Altogether seven different roadtrain models were generated with different trailer axle combinations. The first model was equipped with no steering trailer axles. Three models were configured with one steering trailer axle as the last axle of each trailer, each model with a different steering axle concept. The remaining three models were equipped with two steering trailer axles on each trailer.

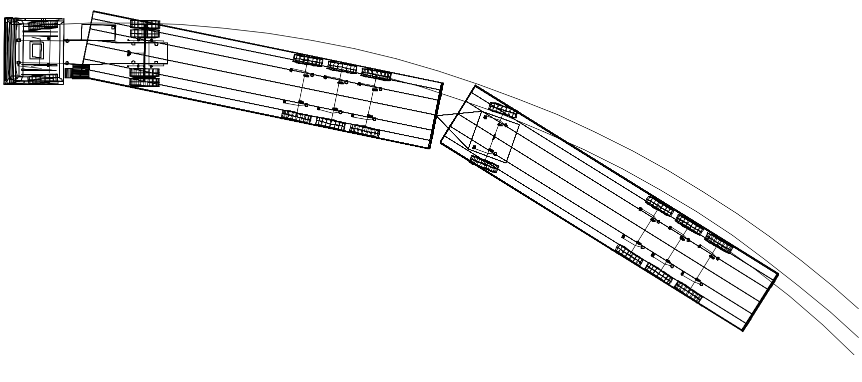

Fig. 2-1: ADAMS roadtrain-model

To validate the simulation results, at first the original truck-trailer combination was examined in the “BO-Kraftkreis”-manoeuvre. As can be seen from fig. 2-2 the trailer axles slightly cut in the inner circle. The reason for this small discrepancy from reality is the modelling of the tyres. The simulation of this special manoeuvre makes the tyres of the trailer turning with extreme slip angle. The characteristic curves do not provide exact data for this magnitude of slip angle, because this range cannot be set on a test bench. So no measuring data can be provided for the simulation.

Concerning the cornering ability the models, which were configured with two steering stub axles respectively two fifth- wheel steering axles on each trailer, showed the best results. They fulfil the demands of the German “BO-Kraftkreis” (Fig. 2-2). The first model without steering trailer axles is not able to drive the circle correctly. One important task was to find out a steering characteristic for the trailer axles. The chosen coherence sets the steering angle of the trailer axles depending on the angle between truck and first trailer respectively between coupling tow-bar and second trailer at the corresponding axles. The steering characteristic represents a linear coherence between these two parameters. This linearity simplifies the realization of the steering actuators.

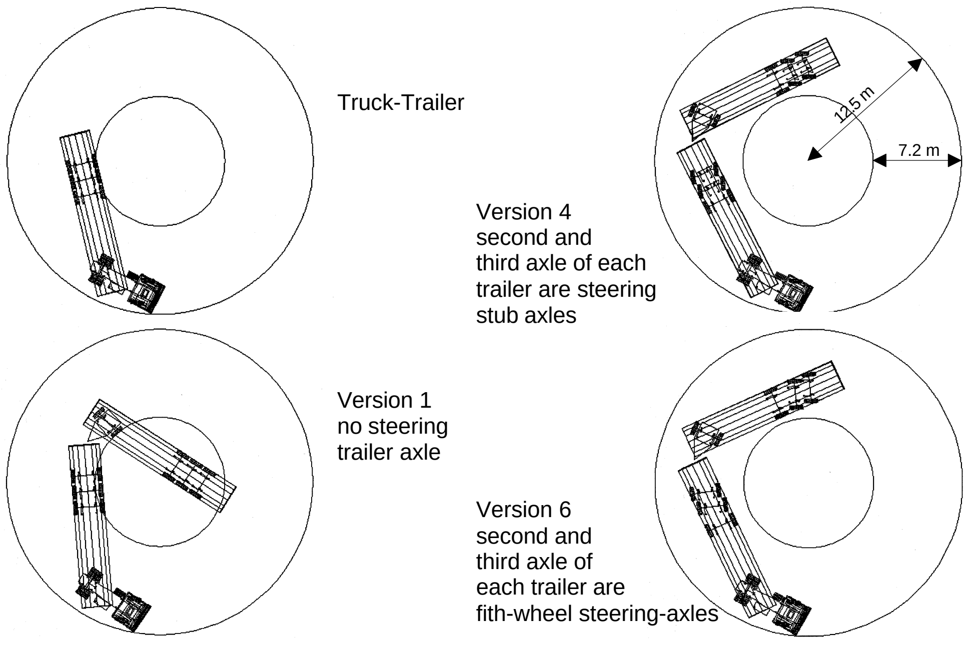

Fig. 2-2: “BO-Kraftkreis”-manoeuvre: simulation results

Further investigation was done on the improvement of dynamic stability of the roadtrain. Up to now the following standard driving manoeuvres were examined:

- Handling on circular course,
- Lane change,
- Steering-angle jump.

The figures 2-3 and 2-4 show the results of the lane change and steering-angle jump manoeuvres for the model without steering trailer axles.

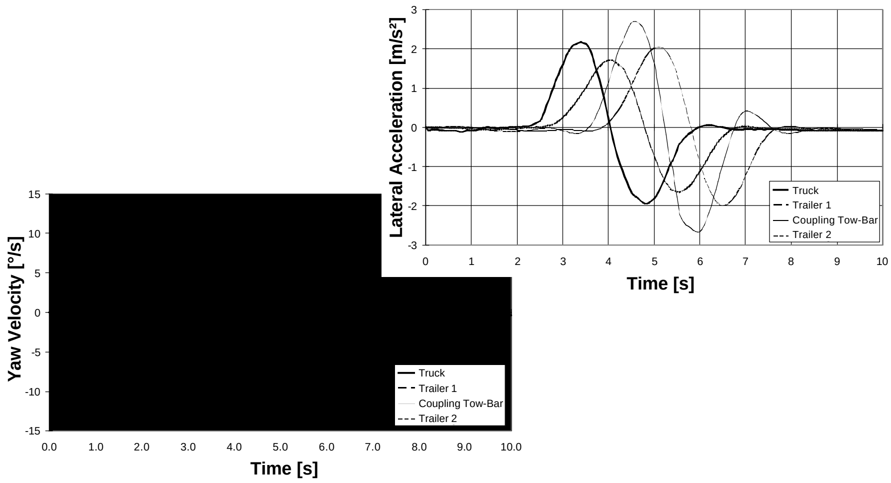

Fig. 2-3: Lane change manoeuvre: simulation results

As can be seen the most critical parts of the roadtrain from the lateral dynamics' point of view are the coupling tow-bar and the second trailer. The steering-angle jump manoeuvre shows a maximum overshoot of 1.3 m/s² for the coupling tow-bar and 1.1 m/s² for the second trailer. In addition the oscillation period up to the stationary value for both is about twice as long as for the first trailer and the truck.

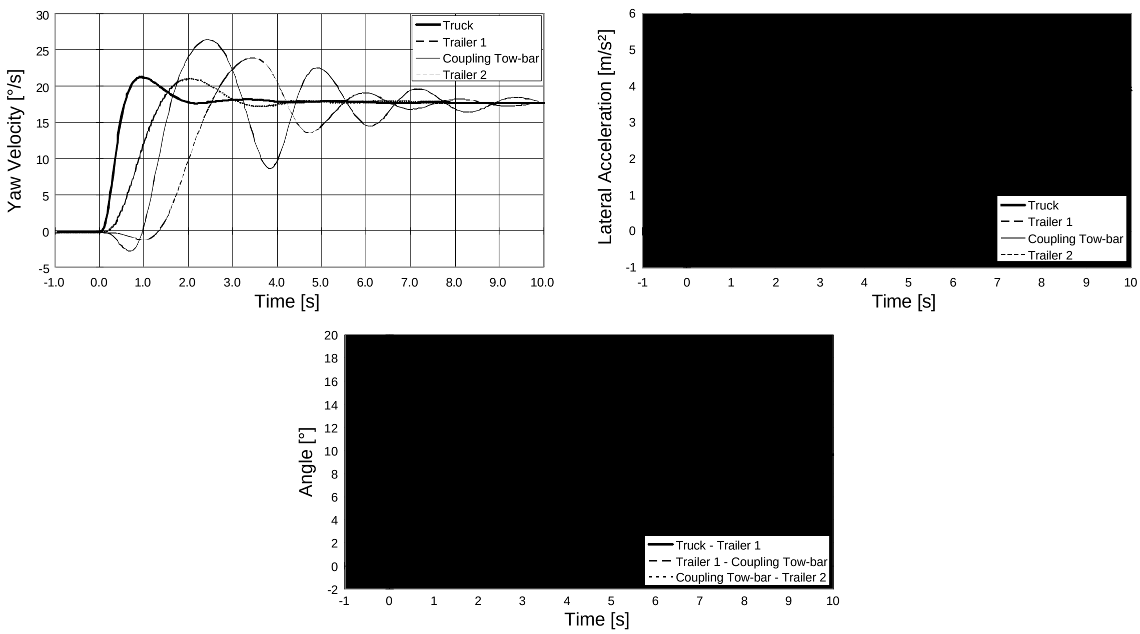

Fig. 2-4 : Steering-angle jump manœuvre : simulation results

Figure 2-5 shows the results of the handling on circular course manoeuvre.

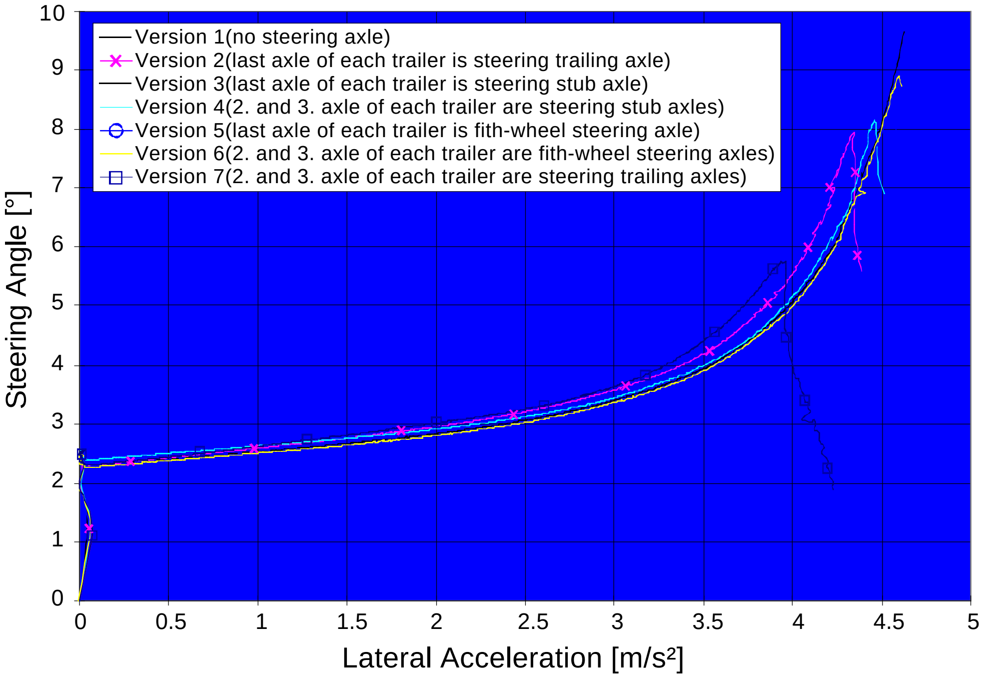

Fig. 2-5: Handling on circular course manoeuvre: simulation results

The model, that is equipped with two steering trailing axles on each trailer, shows the worst handling characteristic. It starts to swerve at a lateral acceleration of 3.9 m/s². The steering trailing axles provide a much smaller amount of cornering stability than the other trailer axle concepts. The best results were found for the model without steering trailer axles. Here the handling characteristic behaves understeering up to a lateral acceleration of about 4.6 m/s².

3 Effects on fuel consumption and traffic flow

In addition the effects on longitudinal dynamics and traffic flow were analysed employing the ika/fka- simulation tool PELOPS (Program for the Development of Longitudinal microscopic traffic Processes in a system relevant environment). The analysis of the interchanges between vehicle, man and environment under particular consideration of the influence of the automobile on this whole system is the task of this program system [LUD98]. The simulator was developed by ika/fka in co-operation with BMW and is today maintained and distributed by fka. PELOPS represents a combination of vehicle- and traffic-specific models, it’s advantage being the possibility to take all interchanges into considerations that occur between driver, vehicle and traffic. The centre of the program is formed by the three crucial elements of traffic systems - stretch/environment, driver and vehicle. With these elements PELOPS is able to simulate traffic in an up-to-now unreached accuracy [HOC98]. In a modular program structure the named elements are modelled and defined by interfaces. PELOPS is used for the evaluation of traffic- and infra-structure-supported traffic influence measures and driver assistant systems. The evaluation follows in form of macroscopic (through-put), microscopic (time laps) and sub-microscopic (emissions) parameters.

For the analysis of a roadtrain concept on fuel consumption and traffic flow a truck equipped with a modern 270 kW engine was simulated with PELOPS. The drive train is designed for a maximum load of 40 t. The roadtrain is realized by an adhered second trailer and so the payload is increased up to 48 t.

The first investigation done with the simulation tool PELOPS involved the analysis of the influence of increased velocity and payload on the fuel consumption and the exhaust gas [WAL99]. For the simulation of fuel consumption a part of a route was chosen, the trade journal “lastauto-omnibus” uses as a standard testing route. The maximum gradient of this route amounts to 4 %. This means comparatively unfavourable circumstances for the operation of a commercial vehicle with a top speed of 100 km/h and enlarged payload. The standard truck with 40 t maximum load consumes 40.5 l per 100km driving the testing route. An increase of speed limit up to 100 km/h results in a raise of fuel consumption of about 5 % on this special testing route. Increasing the maximum load simultaneously up to 72 t (road-train) the fuel consumption of the vehicle amounts to 47.5 l per 100 km. So to transport one ton of cargo over a distance of 100 km a roadtrain needs 0.66 l of fuel compared to 1.01 l of a standard truck. This means an improvement in fuel consumption of more than 34 %, even though the chosen testing route was very pretentious including a considerable share of gradient. The results are visualized in fig. 3-1.

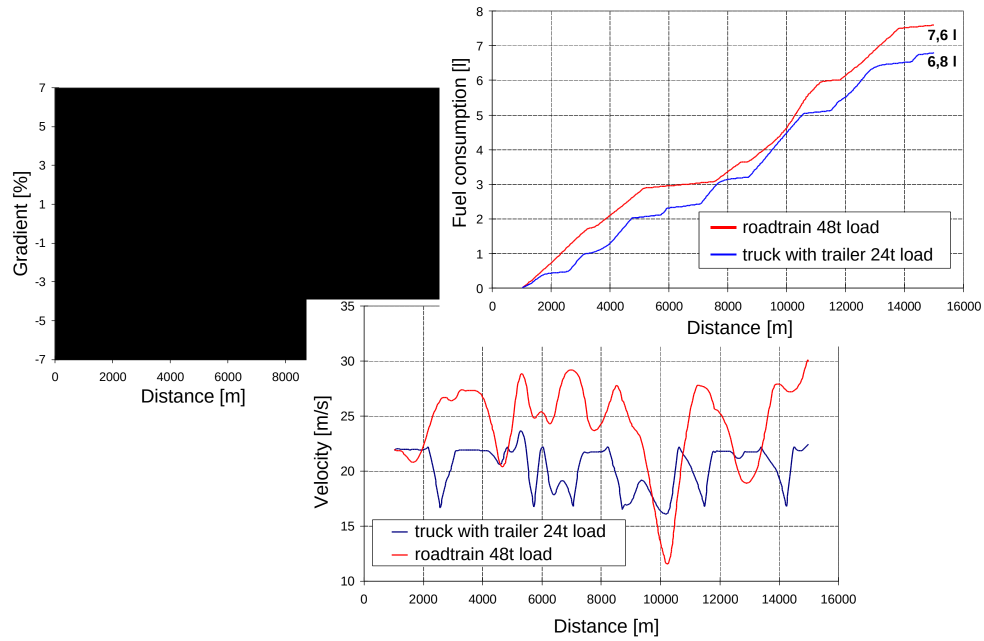

Fig. 3-1: Roadtrain: fuel consumption

Additionally it has to be considered, that at present for a transportation capacity of 48 t two standard trucks and two drivers have to be provided. The roadtrain needs just one truck and one driver as well.

The effects on the traffic flow are investigated by the simulation of a two lane highway for medium and high traffic load (German Autobahn A61 from Cologne to Koblenz). In both cases the percentage of trucks amounts to 25 %. An increase of the speed limit from 80 km/h up to 100 km/h results in an enhancement of average speed by 10 % up to about 120 km/h for a medium traffic load. In the case of high traffic load the enhancement amounts to 14 %. Fig. 3-2 shows the results of this investigation.

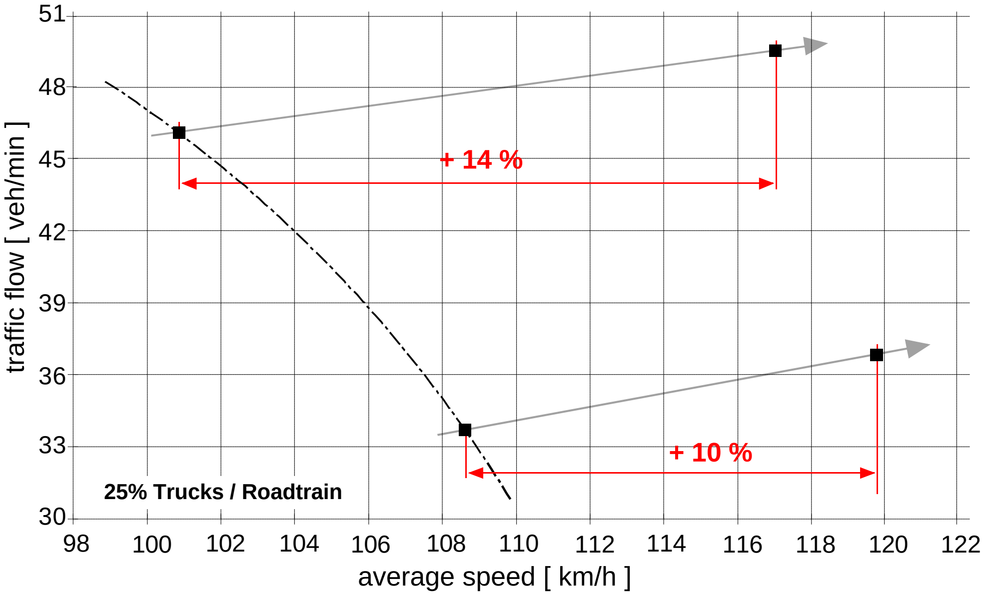

Fig. 3-2: Improvement of traffic flow

4 Summary and further outlook

The results of this first analysis of the influence of the roadtrain-concept and speed limit 100 km/h for trucks show, that for the traffic flow as well as for the efficiency of freight transportation a considerable improvement can be expected. The investigation of the cornering ability showed, that the demands defined by the german "BO-Kraftkreis" can be fulfilled by employing steering trailer axles. The best handling characteristics boasted the model without steering trailer axles. So it seems to be opportune to provide steering trailer axles to improve the cornering ability at low speeds and block the steering function at higher speeds to improve the dynamic stability. Although the model without steering axles showed the best handling characteristics, it behaves not satisfying. The standard driving manoeuvres show some critical vibrations with overshoots in the simulation. Here new technologies like Electronic Stability Program (ESP) can help to improve the handling characteristics and reduce the vibrations of the whole truck combination. The investigation of the fuel consumption showed a considerable reduction of 34 % per ton payload for the roadtrain with a speed limit of 100 km/h in comparison to the standard truck-trailer with 80 km/h speed limit. Further investigation will help to number this improvement more exactly.

These investigations can serve as a groundwork for the conception of a roadtrain for the european traffic environment. Further development should consider the following criteria particularly:

- Conception of an optimised vehicle for a speed limit of 100 km/h and increased payload (accommodation of drive train, brake system, etc.).
- Accommodation of the trailer to the new vehicle concept.
- Consideration of electronic systems in the analysis, e.g. ESP (Electronic Stability Program) or ACC (Adaptive Cruise Control).
- Analysis of the influence of different shares of roadtrains and speed limit 100 km/h.
- Detailed investigation of fuel consumption and exhaust gas of the single vehicle and the entire traffic.

The approach to enlarge the transport capacity of trucks with the roadtrain concept offers a considerable number of advantages. An individual advantage for the users is a significant cost reduction, which is caused by a lower fuel consumption per ton kilometre and lower cost for the driving personnel. An advantage for the community is an improvement of the road capacity (traffic flow) as well as a reduction of the pollution. To exploit the potentials of the roadtrain concept the research on this topic has to be pursued.

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