

# Opportunities to Investigate the Steering System for Improvement of Truck Driving Properties under Critical Road Conditions

Mirosław Gidlewski\*

Received November 2010

## Abstract

Application of an electric steering system in a truck gives new opportunities to obtain desirable and safe motion path under critical road conditions. Analysis of the opportunity to take advantage of the steering system for improvement of truck driving properties will be carried out on the basis of the results of model tests. The paper describes model of the vehicle applied in simulation tests and methodology as well as anticipated results. The scheduled tests will be carried out within the framework of an research project No. NN509 568439 headed by the author.

**Keywords:** car active safety, steerability and motion stability, car driving properties, simulation, critical road conditions, trucks, electric steering system

## 1. Introduction

Steering a modern vehicle in normal road conditions does not cause practically any problems, even to a driver with average skills. However, during vehicle operation occur certain critical road conditions when the driver is forced to do sudden and very often – wrong emergency maneuvers which may lead to the loss of motion stability and in a consequence – to a collision or road accident. To minimize the number of such cases, a modern vehicle is equipped with devices that signal emergency on the road and support and even replace the driver at executing (in the future also at choosing) effective defensive manoeuvres.

---

\* Radom Technical University, Faculty of Mechanical Engineering, Institute of Vehicle and Machine Exploitation, 26-600 Radom, ul. Chrobrego 45, e-mail: miroslaw.gidlewski@pr.radom.pl

Cars (also trucks) manufactured today are equipped with devices that monitor possible vehicle motion path and warn the driver about possibility to abandon established course as well as with devices that monitor and control a distance of the vehicle from other road users and emerging road obstacles. There are also in widespread application systems supporting the driver in steering, such as: Anti-lock Braking System ABS, Anti-Slip Regulation ASR, Electronic Stability Program ESP or Brake Assist BAS. All of these inevitably leads to replace the driver with an automatic steering system i.e. to eliminate the most unreliable element of the system Driver – Vehicle – Environment. A necessary step to achieve this goal is application of an electric steering system in vehicles.

Nowadays, intensive research is carried out all over the world on the application of an electric steering system in vehicles. Many technical solutions of such systems were worked out and patented. Some of them are practically applied in personal cars. However, it should be stated that topics related to application of an electric steering system in vehicle steering improvement are still on preliminary stage – identification of opportunities – regarding mainly personal vehicle steering.

In Poland, problem related to application of an electric steering system in vehicle steering is much worse recognized, especially in case of trucks. In comparison with personal cars trucks have specific properties such as: big changes of shock absorber masses and their moments of inertia, substantial displacement of the mass centre due to the loading way, great tendency to fall over and forces acting on elements of the steering system that vary over a wide range of values. Facts mentioned above confirm that problems presented in the paper are very important.

## **2. Research Methodology**

Analysis of the opportunity to take advantage of the steering system for improvement of truck driving properties will be carried out on the basis of the results of model tests.

In simulation tests will be used a truck model worked out and verified during earlier research done by the author of this paper.

### **2.1. Characteristics of the vehicle model**

Physical model of the vehicle was built on the basis of tests and observations of a typical, two-axle truck of medium load capacity. The considered vehicle has a body integral with frame with attached rails of front and rear axles. Each axle is joined by two longitudinal leaf springs, which also play the role of spring-damping elements of individual suspensions in the vehicle. A structure of the physical model of the vehicle is presented in Fig. 1.

Physical model of the vehicle is a three-dimensional discrete dynamical system which takes into account all the most important degrees of freedom of a real object.

It consists of seven rigid bodies (vehicle body, front axle, rear axle and four wheels). The bodies are joined by compliant elements having non-linear spring and damping characteristics.

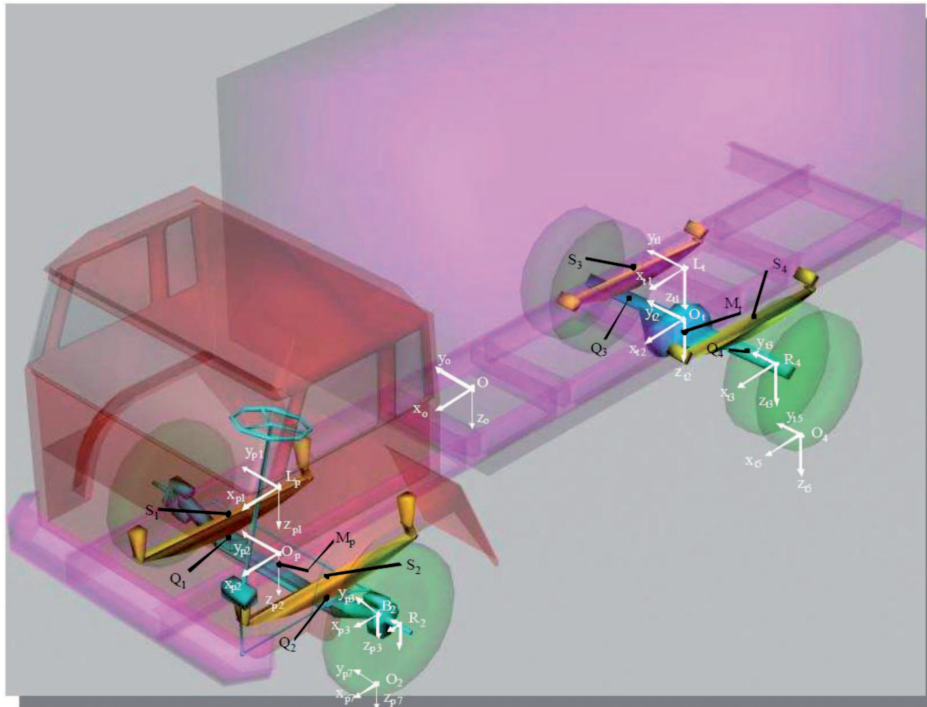


Fig. 1. General view of the truck model; characteristic points and coordinate systems

The model has twenty degrees of freedom. Six degrees of freedom has the vehicle body. It can move in longitudinal, transverse and vertical directions as well as it can rotate about three coordinate axes  $x_0y_0z_0$  of the O system (Fig. 1) that is rigidly joined with the vehicle body. The rail of the front axle and the rail of the rear axle have four degrees of freedom each. Both vehicle axles can move progressively and rotationally in the planes  $Oy_0z_0$  and  $Ox_0y_0$  (Fig. 1). Front wheels have two degrees of freedom each. Each wheel can rotate about the corresponding swivel pin and about its own symmetry axis perpendicular to the median plane of the wheel. Rear wheels (“twins”) have one degree of freedom each. They can rotate about its own symmetry axis perpendicular to the median plane of the wheel.

The vehicle model assumes classical steering system. Model of the steering system takes into account its geometry, kinematics as well as spring and damping properties. Wheels have factory camber and caster angles.

Model of the tired wheel describes interaction between the wheel and flat road surface. It takes into account spring – damping properties of the wheel in the radial and transverse directions.

Dugoff, Fancher and Segel theory, supplemented by investigation results obtained in Braunschweig by Professor M. Mischke, was applied to describe forces and torques acting in the contact zone of the wheel with the road. The applied model of a tired wheel enables to simulate the vehicle motion in variable slip conditions.

Enforcements that act on the vehicle are: forces and aerodynamic torques as well as brake and/or drive torques acting on individual wheels.

Mathematical model was built using the Boltzmann-Hamel method in quasi-coordinates. As a result, there were obtained twenty second-order differential equations which correspond with twenty degrees of freedom of the dynamical system. The equations were supplemented with eight equations of kinematic loops and six equations of geometric loops.

Mathematical model of the vehicle takes into account the presence of the following systems: Anti-lock Braking ABS, Anti-Slip Regulation ASR and Electronic Stability Program ESP.

The model of vehicle was thoroughly and completely verified by experiments carried out during realization of the research project No. 8T07C 009 20 [1, 2].

The worked out model will be completed with a new model of the steering system [3, 4, 5] as well as with new models of interaction between tired wheels and road surface [6]. Working out of these models will be supported by experimental research on the steering system and large-size tired wheels in order to determine parameter values of individual models.

It will be presented the idea of an electric steering system consisting in supplementing the classical steering system, applied in trucks, with a planetary gear powered by an electric motor. In justified cases, the model will enable changes of kinematic gear ratio of the steering system as a result of putting into operation the planetary gear by an electric motor. In critical road conditions, it will enable to accelerate or decelerate changes of steering angles in relation to changes of steering wheel angles. In extreme cases, it will enable to make independent the steering angles of the steering wheel angle executed by the driver. Vehicle motion stability will be a priority which means that an electric steering system will be a subordinate system in relation to the Electronic Stability Program ESP. It is also assumed that the working out programme of steering with the "electric steering wheel" will be correlated with systems monitoring road and traffic conditions around the vehicle.

## 2.2. Simulation research

Simulation research will be carried out using computational software which enables to simulate the vehicle motion in any situation and to simulate standard tests applied in investigation on vehicle driveability and stability.

The worked out computational software requires to enter over 200 parameters of the vehicle model. Values of these parameters were determined on the basis of STAR 1142 technical documentation as well as using results of experimental investigation on this truck and its subassemblies.

There will be carried out simulation and analysis of the model vehicle motion in the following tests:

- steady-state circular course riding,
- sudden steering wheel angle change,
- braking straight ahead,
- single and double lane change.

Simulation results will be used to determine the boundary values of truck motion parameters for various loading options of the load-carrying body and various tyre-ground adhesion coefficients. The values will be used to predict occurrence of critical road situations.

Model of the truck will be applied to carry out many simulations of passing the suddenly emerging obstacle on the vehicle motion path. In the first stage of investigation, the vehicle model will be equipped with classical steering system model. In the successive simulations, the distance between moving vehicle and obstacle will be changed for given vehicle moving velocity and road surface state. This will enable to determine steering wheel angle courses (runs) indispensable to pass the obstacle collision-free. It will also be determined the minimal distances between vehicle and obstacle, at which passing the obstacle will be impossible.

In the second stage of investigation, the vehicle model will be equipped with the model of electric steering system. A series of simulations of the manoeuvre of passing the suddenly emerging obstacle will be carried out taking into account results obtained in the first stage of investigation. In simulations, an electric steering system will be used to increase the rotational speed of steering wheels in relation to the rotational speed of steering wheel. There will be determined signals and their boundary values beyond which an electric motor will be switched on and power the planetary gear. A computational programme will be worked out to determine desirable course of the angle of rotation of electric engine rotor as well as to determine final values of vehicle steering angles necessary to pass the obstacle collision-free. The computational programme will take into account various options of load-carrying body loading and various road surfaces. It is intended that at the beginning, one dominant of the given vehicle motion path prognosis will be collision-free passing the obstacle. In further investigation, steering with an electric steering system will be correlated with systems monitoring road and traffic parameters around the vehicle.

It is assumed that results of the carried out model tests will enable complete analysis of possibilities to improve steering the vehicle motion path at passing the suddenly emerging obstacle with the use of an electric steering system.

### **3. Conclusions**

Carrying out a number of truck motion simulations under complicated road conditions will enable:

- to determine boundary values of motion parameters of a standard, medium load capacity truck under critical road conditions,
- to determine signals and their boundary values beyond which an electric engine will be switched on and power the planetary gear,
- to work out a computational programme to control an electric engine powering a planetary gear, enabling collision-free passing the suddenly emerging obstacle,
- to carry out analysis of effectiveness of supporting the driver with assumed steering system during the manoeuvre of passing the suddenly emerging obstacle.

Additional result of investigation will be working out a helpful and effective tool for supporting the design of active safety systems in trucks.

*Investigation was carried out within the framework of an research project No. NN509 568439 financed by the Ministry of Science and Higher Education*

## References

1. Bedner E.J., Chen H.H.: A Supervisory Control to Manage Brakes and Four-Wheel-Steer Systems. SAE Technical Papers, Inc 2004.
2. Chabaan R.C., Wang L.Y.: Vehicle electric power assist steering system and method using angle based torque estimation, US Patent number: US 6, 293, 366, Date of Patent: Sep.25, 2001.
3. Gidlewski M., Luty W.: Badanie ogumienia samochodu ciężarowego w warunkach dynamicznego hamowania podczas toczenia ze znoszeniem bocznym, IV Konferencja Naukowo-Techniczna. Problemy bezpieczeństwa w pojazdach samochodowych. Materiały konferencyjne. Kielce 2004.
4. Gidlewski M.: Model of a dual axis heavy truck for handling studies in complex road situations, 11th European Automotive Congress Budapeszt 2007.
5. Mc Cann R.A., Badawy A.A.: Method and system for improving motor vehicle stability incorporating an electric power steering system, US Patent number: US 6, 499, 559, B2, Date of Patent: Dec. 31, 2002.
6. Pacejka H.B.: Tire and Vehicle Dynamics. SAE Edition. Society of Automative Engineers, Inc. 2006.