DEVELOPMENT OF MODEL FOR TESTING OF DRIVING PROPERTIES

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Abstract

Technical University of Liberec prepares a functional car model with a four-wheel steering in a reduced scale (1:5). For years, reduced scale models have been a valuable tool (especially in the aircraft and ship industry) for analyses of properties and experimenting. Consequently, experiments, which would be otherwise unrealistic, can be made, the system functionality can be verified and the impact of slight changes and design modifications can be analysed. All of this within a relatively short period of time and at low costs.

The paper presents the application of a reduced scale car model for the 4WS (Four-Wheel Steering) system development and practical assignment necessary for set up. Also shows the use of individual components for functional implementation of this system. The 4WS system pursues the target of enhanced overtaking stability, elimination of positional variances towards its vertical axis, lower sensitivity to side wind, neutral cornering behaviour etc., thus higher active safety.

On the basis of results of driving tests of the scale model and after evaluation of parameters of steering behaviour and driving stability, the computer simulation model of the vehicle could be refined. The reduced scale vehicle model, equipped with the respective sensors of quantities and actuating units, allows carrying out driving tests under laboratory conditions, verification and possible optimisation of algorithms for the control of direction steering of the model is presented in the paper.

Keywords: *4WS, Four-Wheel Steering, Scale car model*

1. Introduction

For many years, reduced scale models have been an important tool, in particular in the aircraft and shipbuilding industry, for analyses of properties. In this way, it is possible to carry out experiments which would be otherwise utterly unrealistic, to verify the system functionality and to analyse the effect of slight changes and modifications upon the design, all this within a relatively short period of time and at low costs. Important is also the reduction of risks that would be related with experiments in operation of a full scale vehicle.

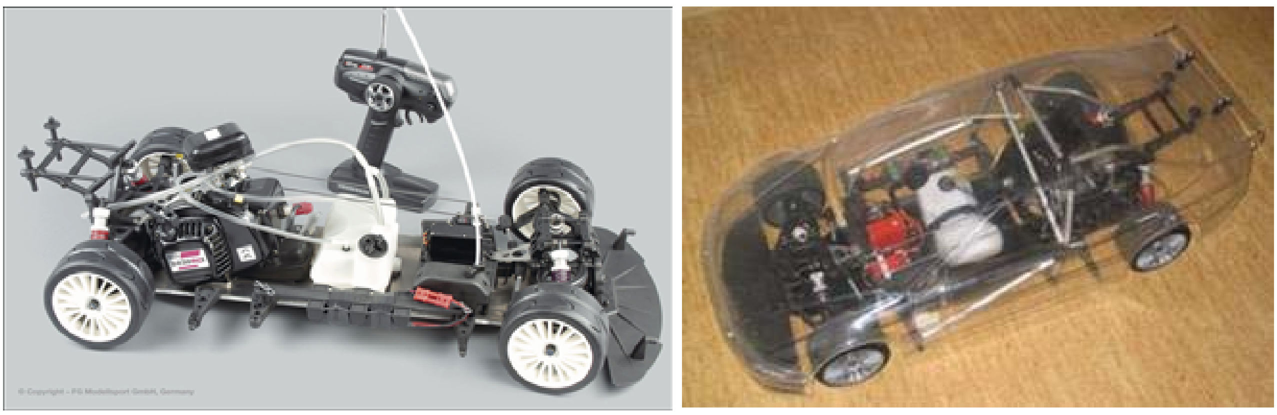

Fig. 1. Model of vehicle (in scale 1:5) –vehicle building kit of firm FG Modellsport [1]

The advantages of work with the model and the availability of commercial building kits of scale car models as well as of individual parts have led to employment of this method in the development of new concepts in the design of cars and intelligent transport systems as well. In some university centres, such models are being employed for testing of systems or of accessories – e.g. adaptive cruise control, by-wire systems etc. In this way, the automobile industry in the development of „novelties“ employs the results of simulations and experiments with models, both using similarity in the analysis of parts exposed to dynamic stress or optimisation of the outside shape with respect to aerodynamics, and in the design or innovation of structural parts of vehicles, with the aim to obtain better functional properties.

2. Model of the automobile

The employed model is provided with double-wishbone axles, which are adjustable in all senses; moreover, the automobile is equipped with exchangeable and adjustable suspension units. The powered rear axle is equipped with a differential. This vehicle model will be set with sensors and necessary accessories for the data collection during the drive of the automobile. The rpm sensors, which will be situated in the wheels, will transmit the information on the speed of revolution of individual wheels of the vehicle into control computer. The control computer will evaluate the information – on the direction variance of individual wheels, but also on a potential deviation of the vehicle (moreover, the computer processes the data provided by sensors of transversal acceleration and of the yaw rate).

An important part of the solution of this phase of the project has been the choice of the control computer and of suitable sensors that will provide for collection of all necessary data and evaluation of the quantities. The sensors intended for employment in the automobile model must have met the following requirements:

- possibility of installation of the sensor and accessories,
- mechanical endurance of the sensor,
- a suitable way of data collection from the sensor,
- a convenient range for measuring the quantity in question.

To verify the properties of chosen sensor, to verify the measured quantities and to ascertain the time course of the output signal, we have used also a multi-channel analyser PULSE of the firm Brüel & Kjaer.

Control computer

The model of the vehicle will be provided with a „reduced scale“ personal computer (VIA EPIA NL10000 Nano Low ProfiIe ITX, integr. CPU VIA Luke/Eden-N 1GHz), which will evaluate the data from the sensors. The mobile control computer will be fed by 12 storage cells (12x 4300 mAh).

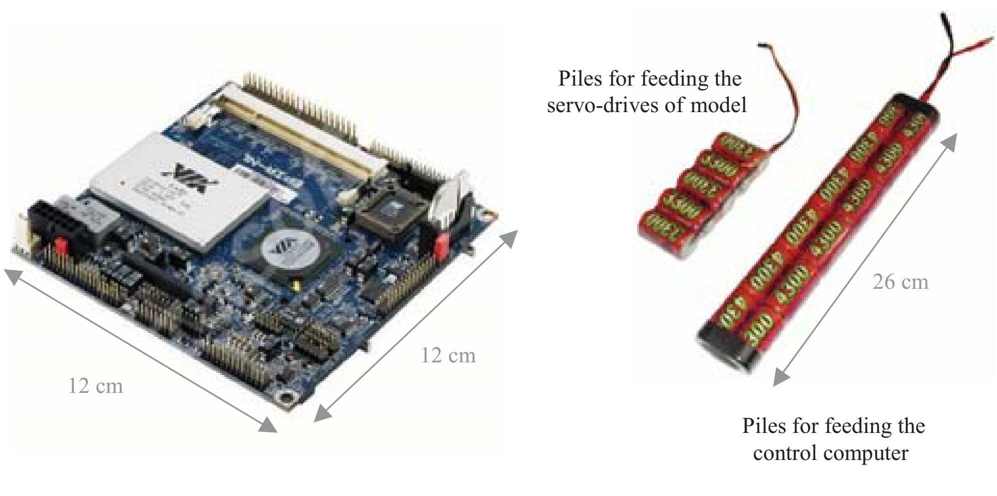

Fig. 2. Control computer and piles required for its feeding

Rpm sensor

For establishing the angular velocity of the driving unit there has been proposed an incremental rpm sensor, which will be connected to the shaft of the combustion engine. The angular velocity of individual wheels will be established on the basis of picked up pulses. For this purpose, there has been devised the configuration shown in the Fig. 3, namely 72 miniature magnets, arranged at a spacing of 5 degrees on the inner circumference of the wheel rim, and a Hall probe. This solution allows monitoring the measured quantities of velocity. The choice of the rpm sensor must have been effected in two steps. The original idea of installing a precise 8- or 12-bit incremental sensor in each wheel has run up against problems with the installation and low resistance of the sensor to impurities. Therefore, this type of sensor has been proposed for measuring the rpm of the combustion engine of the model. For accurate measuring of rpm of individual wheels, there has been chosen a Hall probe and a tape containing 72 magnets, which will provide for reading the changes in the wheel revolution by 5 degrees.

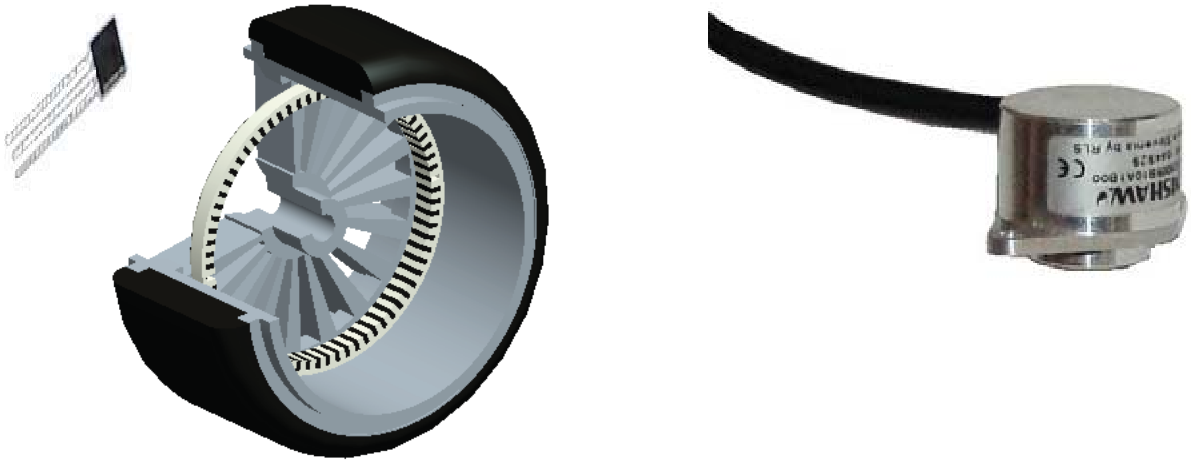

Fig. 3. Sensor of wheel revolutions (Hall probe) and rpm sensor of the combustion engine

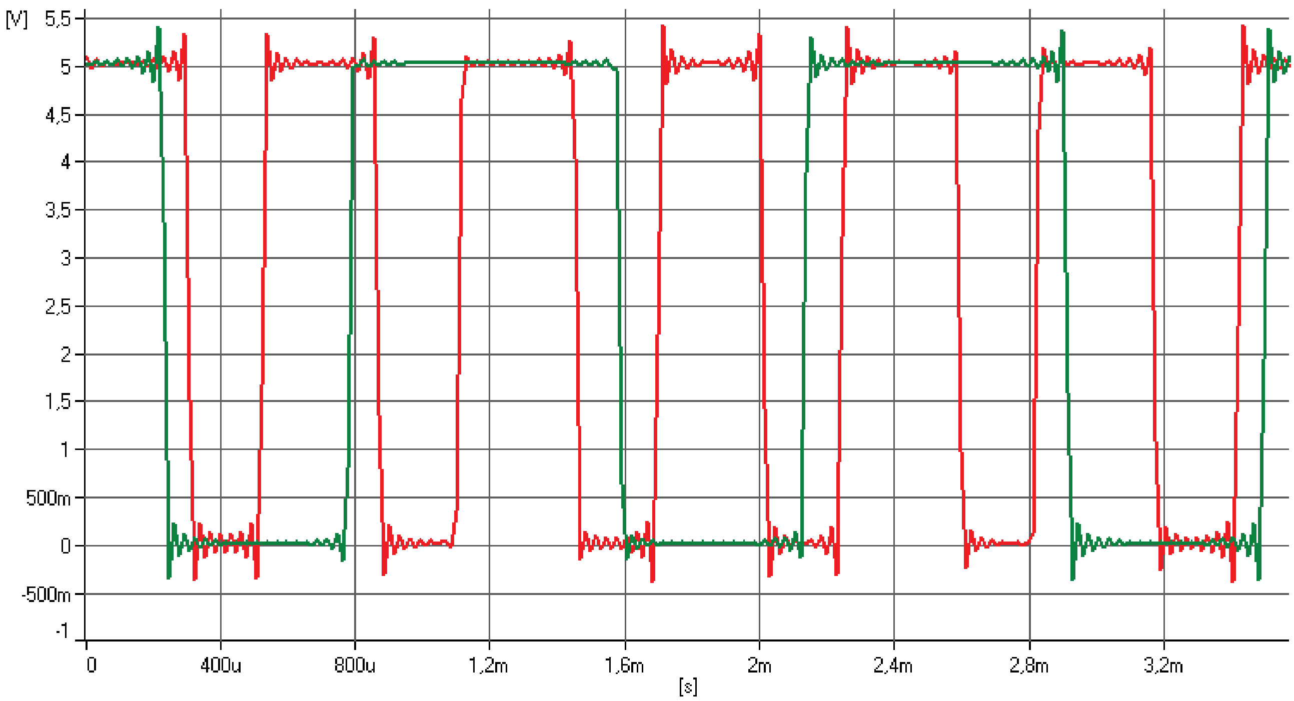

Fig. 4. Time courses of voltage on the output of the Hall probe (red – higher velocity of revolution)

Acceleration sensor

For establishing the dynamic forces influencing the model in transversal and longitudinal directions, there has been employed an acceleration meter of the firm Analog Devices. This sensor offers the advantage of communication by the system bus bar, allowing for an easy transfer to USB interface, present on the panel of the control computer.

Fig. 5. Acceleration sensor

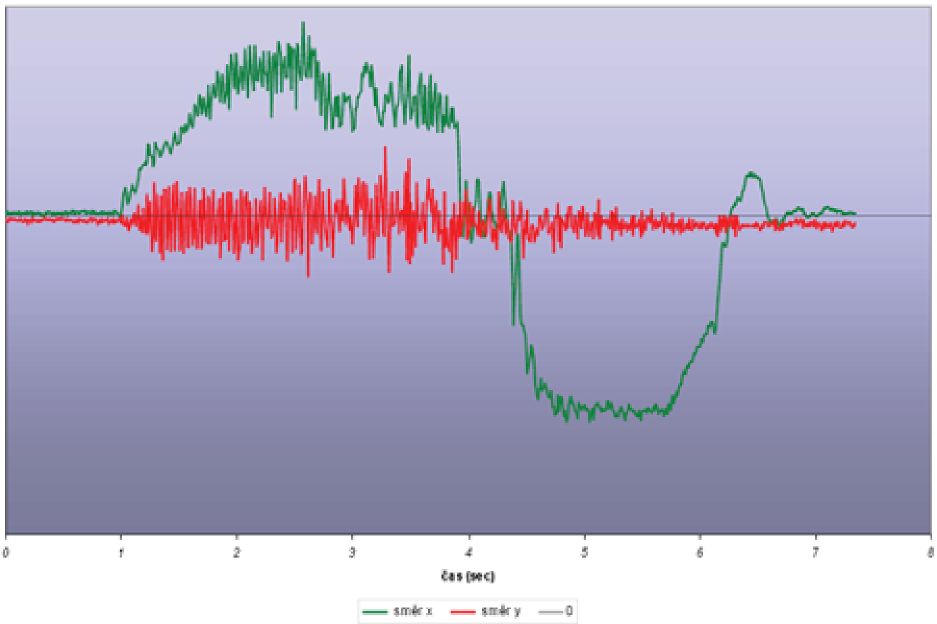

Fig. 6. Measuring of acceleration in the vehicle Škoda Octavia – moving off, trailing throttle (time (sec.); green line=longitudinal direction, red line=lateral direction)

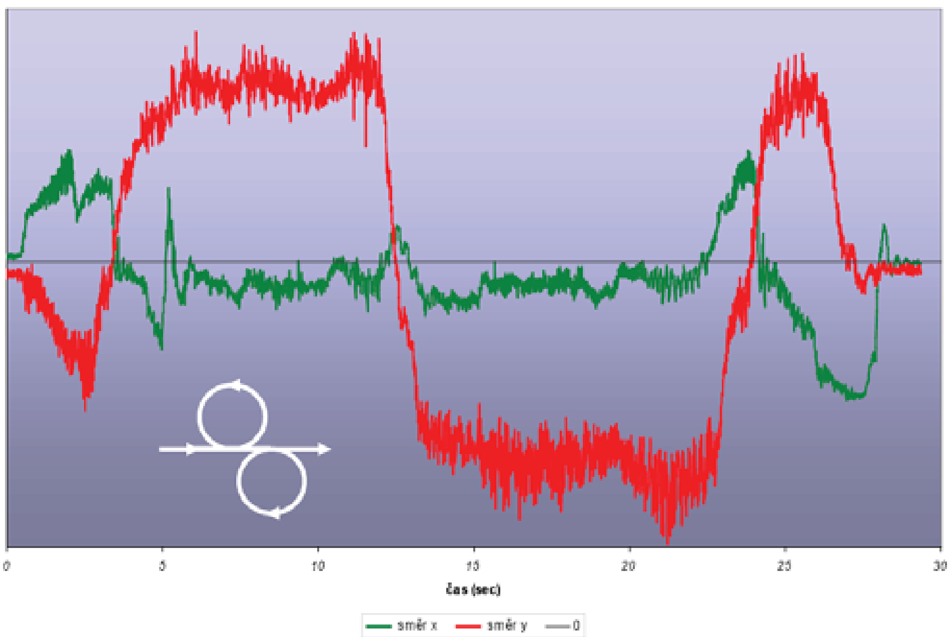

Fig. 7. Measuring of acceleration in the vehicle Škoda Octavia – cornering (time (sec.); green line=longitudinal direction, red line=lateral directions)

Sensor of yaw rate of the vehicle

For measuring the yaw rate of the vehicle, there will be used a sensor of the type Single Chip Yaw Rate Gyro with Signal Conditioning (±300°/s). This sensor will be situated close to the centre of gravity of the vehicle, together with the sensor of transversal and longitudinal acceleration.

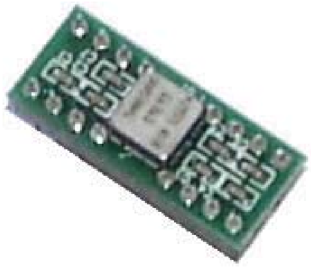

Fig. 8. Sensor of yaw rate

Control signals for servomotors

In order to provide for repeatability of driving tests, it is necessary that the control itself (both the direction steering and the speed control) is secured by the control system of the automobile model. For creating the module for the control, it is necessary to reproduce the signals of control unit of the receiver of servomotors.

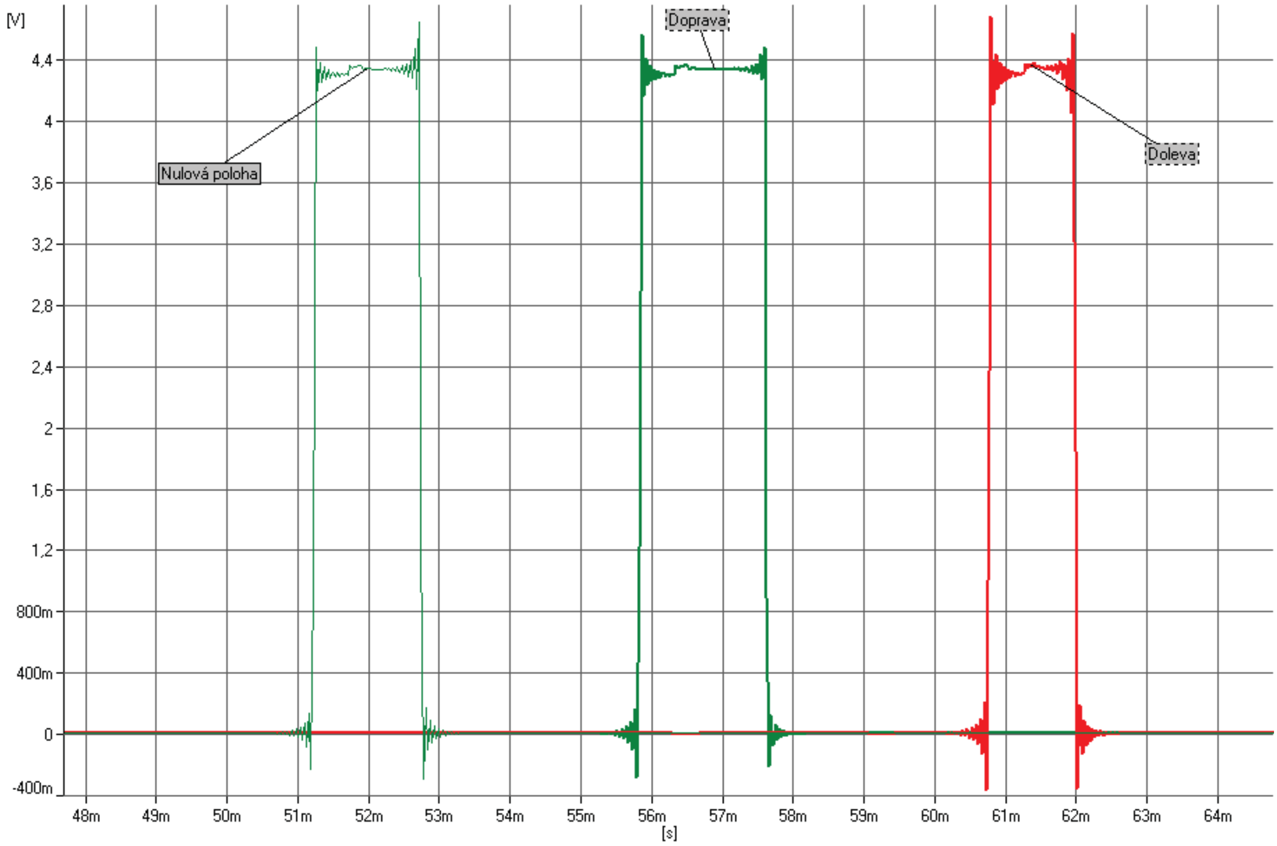

Fig. 9. Time course of the voltage of control signals for servomotor of direction control

3. Establishing of other necessary parameters for the simulation model of the vehicle

The measured data from all the sensors employed in the model of the vehicle during various driving manoeuvres will be employed in the verification of the simulation model of the automobile. For a proper function of the simulation model, we need to know other parameters of the scale vehicle model; first of all, the properties of the tyres. In order to ascertain these unknown quantities, we expect to use the experience of the partner Prague University, which has got a measuring station for this problem (see Fig. 10). Moreover, it is necessary to establish the weight of the vehicle, the position of the centre of gravity and the matrix of inertia moments of the scale vehicle. The necessary measuring will be effected by our Department, because its workers have carried out similar measuring already.

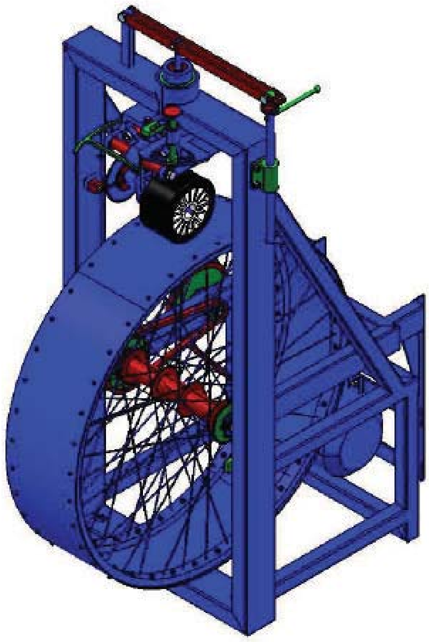

Fig. 10. Station for establishing characteristics of tyres [3]

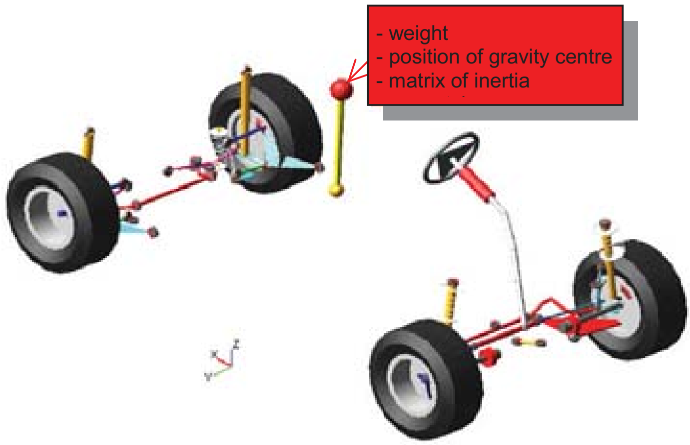

Fig. 11. Example of vehicle simulation model [2]

4. Conclusion – use of the vehicle model set with sensors for the 4WS system

An adequate choice of the sensors of required quantities has represented the first important step. The vehicle model of reduced scale could be used for the design and optimisation of the 4WS system. If the verification of the scale automobile model and of simulation model of the vehicle succeeds, the model also could be used for an optimisation of the control algorithm of the rear axle (for an easy testing of a number of variants). However, the original rear axle will have to be reconstructed to a steered one.

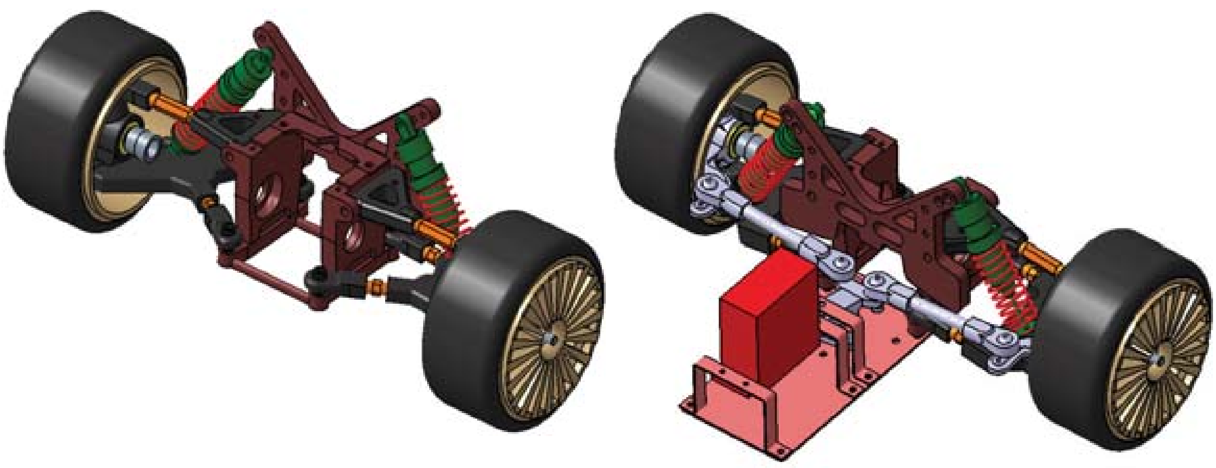

Fig. 12. Adaptation of the rear axle of the vehicle model – left, an unsteered one, right, a steered one [5]

The introduction of actively steered wheels on the rear axle of the automobile has pursued two targets, namely an improved manoeuvrability during slow driving (e.g. for parking), but also an improved stability when driving at high speeds, when even a minute direction variance, may it be produced intentionally or by immediate reaction of the driver to a sudden obstacle, may have a considerable effect upon the drive. The 4WS system pursues the aim of enhanced overtaking stability, elimination of positional variances towards its vertical axis, lower sensitivity to side wind, neutral cornering behaviour etc., i.e. a higher active safety.

The reduced scale vehicle model, equipped with the respective sensors of quantities and actuating units, allows carrying out driving tests under laboratory conditions, as well as verification and possible optimisation of algorithms for the control of direction steering of the model. On the basis of results of driving tests of the scale model and after evaluation of parameters of steering behaviour and driving stability, the computer simulation model of the vehicle could be refined, too.

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