CONTROLS SYSTEM OF VEHICLE MODEL WITH FOUR WHEEL STEERING (4WS)

Abstract: Four-Wheel Steering – Rear Wheels Control. For parking and low-speed maneuvers, the rear Wheel steer in the opposite direction of the front wheels, allowing much sharper turns. At higher speeds, the rest wheels steer in the same direction as the front wheels. The result is more stability and less body lean during fast lane changes and turns because the front wheels don’t have to drag non-steering rear wheels onto the path.

KEY WORDS: Four-Wheel Steering, 4WS, Rear Wheels Control

1. INTRODUCTION

Mainly in aviation and shipping industry, the scale models belong for many years to common methods of experiment implementation. For example, in aerodynamics of aviation structures, the aircrafts’ scale parts or entire aircrafts have been used for experimental determination of aerodynamic characteristics and their optimisation. With the help of similarity theory, using this method, it is possible to obtain relatively accurate experimental results with low costs incurred. It is also possible to execute experiments, which would otherwise be entirely infeasible, verify function of even small-scale variations and modifications of the structure; all this can be done within a short time. Also a minimum risk experienced is essential, which would naturally accompany experiments that are otherwise feasible. These advantages as well as development of commercial sets of scale models have led to utilisation of this method even in the field of development of new resolutions in disciplines of vehicle design and intelligent transport systems design. In case of automotive industry, recent technologies have allowed going beyond this; thus, in addition to aerodynamics, which is focused mainly on the shape of vehicle body and the air flow along car body as well, it is possible, through accurate miniatures of structural parts of vehicles, to make a vehicle that is very similar to real car, including weight proportions and dynamic characteristics.

2. SYSTEM 4WS

Contemporary rear axles allows for coincidental steering through the influence of variation of elastokinematic steering; rear wheels rotate, due to an influence of variation of vertical load of wheels (tilting), in the same direction as front wheels. Nevertheless, such a turn of rear wheels is very small and driver’s will-independent. A disadvantage of this so-called passive steering system is that it operates even when driving in straight direction when single wheel of an axle hits surface irregularity (deterioration of directional stability). New generation of active steering systems distinguishes a need of steering of rear wheels for the reason of directional stability from a need of steering of rear wheels for the reason of cornering at slow speed. Therefore, the active system means that rear wheels are possible to be turned either coincidently or non-coincidently.

The increase of the manoeuvrability when parking the vehicle is achieved by means of disconcordant steering, meanwhile the increase of the driving stability at higher speeds is achieved through concordant steering.

*Pavel Brabec, Eng., Technical University of Liberec, Faculty of Mechanical Engineering, Hálkova 6, 461 17 Liberec, Czech Republic, pavel.brabec@vslib.cz
** Miroslav Malý, Assoc. Prof., Technical University of Liberec, Faculty of Mechanical Engineering, Hálkova 6, 461 17 Liberec, Czech Republic, miroslav.maly@vslib.cz
*** Robert Voženílek, Eng., Technical University of Liberec, Faculty of Mechanical Engineering, Hálkova 6, 461 17 Liberec, Czech Republic, robert.vozenilek@vslib.cz
3. TESTING OF CONTROLLABILITY AND STABILITY ON A MODEL OF THE AUTOMOBILE

As already stated above, experiments are implemented using scaled vehicles. Most of similar experiments in the world utilise sets of German model manufacturer FG Modellsport, which are design-wise very similar to real vehicles and are able to meet basic requirement of ability to transfer the data gained experimentally into reality. Models have been primarily of a hobby nature, but hobby sphere is recently already at a semi-professional level. The world racetrack championship has been put out for models equipped with combustion engines and fastest scale models reach maximum speeds of more than 100 km/h.
Preparation of vehicle model building, all wheels of which are steered, is in progress in the Technical University of Liberec. The building up of our vehicle model is based on the set of the firm FG Modellsport. This semipruduct is equipped with trapezoidal axles which are comprehensively adjustable; in addition, the vehicle is equipped with replaceable and adjustable suspension units. The rear drive axle is equipped with a differential gear unit. Design of original rear axle will have to be replaced by a steerable one. For experiments proper, the model will be equipped with speed sensors of wheel rotation as well as sensor of vehicle acceleration. Input control parameters are the velocity and the angle of wheel angular turn of front and rear wheels.

This model will serve to assess various algorithms of the steering of the vehicle to provide for a higher driving stability (i.e. at higher speeds – concordant steering) including various adjustments of the chassis.

**Figure 3:** Sample of vehicle model

**Figure 4:** Arrangement of the model: 1 – combustion engine, 2 – front axle, 3 – rear axle, 4 – servo drive with the sensor for the front axle, 5 - servo drive with the sensor for the rear axle, 6 – servo drive with sensor for the turning of the engine flap, 7 – control computer, 8 – sensor of the rotation of the wheels, 9 – sensor of the yawing velocity, 10 – sensor of the lateral acceleration, 11 – battery.
4. THE BASIC PHILOSOPHY OF THE ACTIVE SYSTEMS FOR STEERING THE REAR WHEELS

In order to meet these contradictory requirements, it has been necessary to find such a technical solution that may provide either for concordant or disconcordant steering of the rear wheels, depending upon the intended driving manoeuvre. From the technical point of view, it is rather difficult to provide for steering the rear wheels: the wheel suspension must allow for its steering, the design must include actuating elements that will provide for precise adjustment, but in addition, it is necessary to employ a control system that will issue the necessary instructions to the actuating elements.

The systems 4WS are based upon the regulation when the steering angle of the rear wheels depends upon the input parameters (e.g. the angle of the steering wheel, the speed of the vehicle) as well as the output parameters (e.g. the yawing velocity) of the vehicle.

The control system must ensure that the instructions passed upon the actuating elements are precise and that they are passed on quickly. The electronic systems can evaluate the followed parameters rather fast, and they can assign a value to the control quantity that will control the power element. The diagram of the arrangement is shown in the fig. 4. The control unit will decide upon the information of the steering of front wheels, however, the result will be corrected with respect to the instantaneous velocity of the drive, the value of the yawing velocity and the lateral acceleration of the vehicle. The steering of the rear wheels will be checked by the sensor of their position which serves as the feedback to the control circuit.

To resolve the steerability, and for optimisation of steering algorithm and vehicle stability, even a simulation can be used. It is advantageous to utilise a single-track plane dynamic vehicle model as per Fig. 6. When this model is compared with a twin-track model, it can be seen that lateral force on front axle \( S_F = S_1 + S_2 \) and on rear axle \( S_Z = S_3 + S_4 \); the circumferential force \( H_F = H_1 + H_2 \); \( H_Z = H_3 + H_4 \). Rolling resistances and self-aligning moments of wheels are neglected.
Figure 6: Single-track plane dynamic vehicle model

Now, based on Figure 6, three equation of motion can be written down

\[ - m \cdot v \cdot \cos \alpha + m \cdot \dot{v} \cdot (\dot{\varepsilon} + \dot{\alpha}) \cdot \sin \alpha - S_p \cdot \sin \beta_p \cdot \dot{v} - S_z \cdot \sin \beta_z + H_p \cdot \cos \beta_p + H_z \cdot \cos \beta_z - O_v = 0 \]  
\[ (1) \]

\[ - m \cdot \dot{v} \cdot \sin \alpha - m \cdot \dot{v} \cdot (\dot{\varepsilon} + \dot{\alpha}) \cdot \cos \alpha + S_p \cdot \cos \beta_p + S_z \cdot \cos \beta_z + H_p \cdot \sin \beta_p + H_z \cdot \sin \beta_z + N = 0 \]  
\[ (2) \]

\[ - J_z \cdot \ddot{\varepsilon} + S_p \cdot \dot{v} \cdot \cos \beta_p - S_z \cdot \dot{v} \cdot \cos \beta_z + H_p \cdot \dot{v} \cdot \sin \beta_p + H_z \cdot \dot{v} \cdot \sin \beta_z + N \cdot \dot{e} = 0 \]  
\[ (3) \]

By means of linearization and modification of given equations we can obtain equations intended for vehicle lateral breakaway.

Lateral breakaway is determined by values of angle \( \alpha \) (and by corresponding angular velocity). Yaw of the vehicle is determined by angle \( \varepsilon \) (by angular velocity and angular acceleration). The system is excited by the exciting function (variation of steering wheel angular turn) \( \beta_v = \beta_v(t) \), which influences angular turn of both front and rear wheels through gear ratios of steering boxes.

\[ \alpha = -\left(1 + \frac{C_{op} \cdot \dot{p} - C_{az} \cdot \dot{L}}{m \cdot \dot{v}^2}\right) \cdot \dot{e} - \frac{C_{op} + C_{az}}{m \cdot \dot{v}} \cdot \alpha + \frac{C_{az}}{m \cdot \dot{v}} \cdot \beta_z + \frac{C_{op}}{m \cdot \dot{v}} \cdot \beta_p \]  
\[ (4) \]

\[ \ddot{\varepsilon} = \frac{C_{op} \cdot \dot{p}^2 + C_{az} \cdot \dot{L}^2}{J_z \cdot \dot{v}} \cdot \dot{\varepsilon} - \frac{C_{op} \cdot \dot{p} - C_{az} \cdot \dot{L}}{J_z} \cdot \alpha - \frac{C_{az} \cdot \dot{L}}{J_z} \cdot \beta_z + \frac{C_{op} \cdot \dot{p}}{J_z} \cdot \beta_v \]  
\[ (5) \]
The simulation was executed using the program MATLAB Simulink v.5.3.

Figure 7: Simulation diagram of plane model of the vehicle having all wheels steerable
5. CONCLUSIONS

The aim of 4WS system is a better stability during overtaking manoeuvres, reduction of vehicle oscillation around its vertical axis, reduced sensibility to lateral wind, neutral behaviour during cornering, etc., i.e. improvement of active safety.

The model of the vehicle in the scale 1:5 will allow us to follow the behaviour of the 4WS automobile at a much lower cost, and on a smaller scale than with a real automobile. By means of the control computer in the model, we will be able to assess several types of the algorithms for steering the rear wheels. These algorithms will be optimised according to the size and course of the lateral acceleration and the yawing velocity.

6. REFERENCES


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