DSTA 2021 dys-ta.com
16th INTERNATIONAL CONFERENCE
Dynamical Systems – Theory and Applications
December 6-9, 2021, On-line

Reference models of the 4WS vehicle lateral dynamics for the synthesis of steering algorithms.

DĘBOWSKI ANDRZEJ[1] , FARYŃSKI JAKUB[2], ŻARDECKI DARIUSZ[3*].

1. Military University of Technology (WAT) [ORCID 0000-0003-1446-4415]
2. Military University of Technology (WAT) [ORCID 0000-0001-6515-0921]
3. Military University of Technology (WAT) [ORCID 0000-0002-3934-2150]
* Presenting Author

Abstract: The presented paper describes selected reference models describing the kinematics and dynamics of four-wheel steering (4WS) vehicle motion in a plane of the road. These models are based on well known "bicycle model" (two second order linear differential equations) supplemented by non-linear equations of trigonometric transformation of variables from local to global coordinate system. After linearization and Laplace transformation, these models acquire the forms of transfer functions. which, as shown in computational examples presented in the paper, greatly facilitates the analysis of vehicle motion, as well as the synthesis of control algorithms. Especially, transmittance form of the reference models facilitate sensitivity analysis of vehicle lateral dynamics and steering system algorithms, because their parameters are analytical functions of "mechanical" parameters. For synthesis of steering system algorithms which should be adequately effective for on-line computations, the transfer functions can be reduced in several ways. One of them is discussed in the paper.

Keywords: 4WS cars, reference models, control algorithms

1. Introduction

Four-wheel steering (4WS) is one of the distinguishing features of passenger cars equipped with advanced mechatronic systems supporting the driver [2], [3], [4]. In such systems, there are digital controllers coupled by-wire with actuators of steering mechanisms of the front and rear wheels, which allows not only to shape the waveforms controlling the steering of the wheels on-line according to the actions of the driver and the reaction of the driven vehicle, but also to modify the steering when the driver's actions are at risk of an accident. Active steering of the wheels in 4WS vehicles requires appropriate algorithms, the basis of which are reference models describing the movement of the driven vehicle [1], [5], [6]. The role of the reference models is twofold. On the one hand, they are to be an element of the control algorithm, so they must meet the time requirements of on-line calculations, on the other hand, they are to be the basis for the proper design of regulators correcting control signals. Such a situation occurs in the case of the 4WS car control algorithm performing the lane change maneuver. The aim of the article is to present the reference models of 4WS vehicle used in the design of a controller of the lane change process.

2. Results and Discussion

According to a general concept of car control when changing lanes where the controller contains a reference signals' generator (reference waveforms of control and response signals) and a system of regulators correcting the control signals (responsible for shifting the vehicle to a new track and its angular stabilization). The algorithm for generating reference signals and the algorithms of the regula-

tors are based on the reference models of the 4WS car's motion dynamics. These models are derived from the "bicycle model" (which express linear and angular velocities in the local coordinate system related to the moving vehicle) supplemented by the transforming equations (which transform waveforms from the local system to the global system related to the road). It well known from driver practice that steering signal should have a form of short “bang-bang”-type signal for realization of lane change processes. In such case the maximal angle of vehicle deviation is small, so the linearization of the model is possible. Then the linearized model of the 4WS vehicle dynamics, can be presented as “the black box” form with four transfer functions expressing actions of two input signals (angles of front and rear vehicle wheels) on two output signals (linear and angular dislocation of the vehicle body) - fig.1.

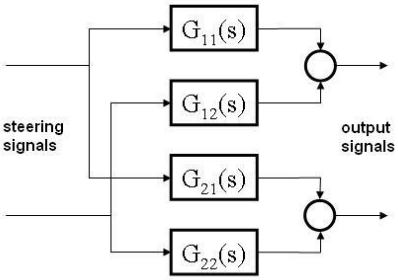

Fig. 1. Idea o transmittance type reference models

The reference models in transfer function forms enable sophisticated analysis of 4WS vehicle lateral dynamics and control processes in time as well as in frequency domain. Note, that transfer functions parameters (gains, time constants, characteristic frequencies, etc), are associated with mechanical parameters (vehicle speed, mass, yaw moment of inertia, wheels cornering stiffness, etc.) by analytical formulae. For synthesis of steering system algorithms, the transfer functions can be reduced in several ways including these analytical dependencies. For example, thanks to omitting “subtle” dynamic components in transfer functions one obtains analytical formulae (important for on-line calculations) describing reference “bag-bang” steering signals (magnitude and time period).

3. Concluding Remarks

The method of synthesis control system algorithms for 4WS vehicles on the base of elaborate reference models seems to be an attractive proposition for engineer s working on autonomous cars.

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