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Modeling and simulation of the automated lane change process, taking into account freeplay and friction in the vehicle steering system.

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Abstract: The paper reports rather unique research on the influence of freeplay and friction in the car steering mechanism on automatically controlled process of lane change. The developed controller algorithm was based on very simplified (and thus effective in on-line calculations) reference models of the car dynamics, obviously without taking into account the nonlinearities of its steering system. Extensive simulation investigations of the developed controller algorithm carried out in a very wide range of changes in road and operational conditions, with regard to two-axle medium-duty truck, confirmed its advantages. The research presented in this article concerns the unpublished area of analyzes concerning the sensitivity of the lane change controller to freeplay and friction occurring in the steering mechanism of a controlled car. Some results of the simulation tests turned out to be surprising The piecewise-linear luz(...) and tar (...) projections used in these studies to describe the freeplay and friction effects facilitated modeling and simulation calculations.

Keywords: automatic lane change, steering system, freeplay, friction, modeling and simulation

1. Introduction

The influence of (backlash, clearance) and friction (viscous and dry friction with stiction) on system control is discussed in a number of publications, see reviews papers [1, 5]. But these works do not relate directly to the automotive issue. Due to the real-time signal processing requirements, the controllers of embedded mechatronic systems are based on relatively simple models describing the dynamics of the controlled car. Therefore, when designing controllers, non-smooth nonlinearities, such as freeplay and friction, which are difficult to calculate, are ignored, which means that in fact the control algorithms created relate only to "new" vehicles. Therefore, it is reasonable to ask about the sensitivity of the designed control algorithms to the appearance of freeplay and friction in the steering mechanisms. Such analyzes are extremely rarely reported in available scientific publications and refer to classic steering systems rather than active systems equipped with controllers, eg. [4, 6]

In previous papers, eg [2, 3], the authors presented design and research works on a steering system controller that automates the process of changing lane by a car when an obstacle suddenly appears. The developed controller algorithm has been extensively tested by simulation in relation to a truck (treated as MBS object, but always without freeplay and friction in its steering mechanism), in a wide range of changes in road and operation conditions. The maneuver to bypass the obstacle in the vast majority of attempts was successful without the need to change the previously adopted assumptions and the determined values of the controller parameters, even in the presence of signals' disturbances. The time has come to extend the scope of research to include the sensitivity of the controller to the occurrence of freeplay and friction in the vehicle steering mechanism.

2. Results and Discussion

This article presents the latest research on the sensitivity analysis of the lane change controller, this time due to the steering gear freeplay and the steering king-pins friction that have been ignored in the design. In connection with the above, the previously used model of the dynamics of a truck, has been supplemented with a fairly detailed model (MBS-type, with non-smooth characteristics, and variable-structure differential equations) of its steering mechanism operation, taking into account freeplay (in steering gear) and friction (in king-pins). In modeling the freeplay and friction nonlinearities, the piecewise-linear luz(...) and tar(...) projections have been used (Fig.1) [7]. They simplifies the synthesis of the model, as well as its functioning in the simulation program.

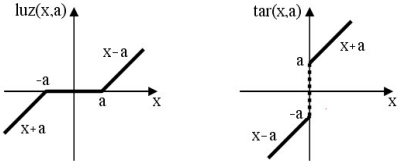

Fig. 1. Geometric interpretations of the luz(…) and tar(…) projections

Due to the expansion of the object model, peculiar phenomena related to the stick-slip operation occurred in the waveforms describing the lane change process. The presence of freeplay and friction in steering system, worsened the effect of lane change control when certain values of these factors are exceeded. The sensitivity of the system to the presence of freeplay and friction increases with the deterioration of road and operational conditions (slippery road, unloaded vehicle, high speed).

3. Concluding Remarks

The simulation studies taking into account the freeplay and friction in the steering system are very important for design the lane change process controller. Such studies should be continued to cover also issues related to electric signal disruptions.

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