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X-by-wire Vehicle Prototype: Automatic Driving Maneuver Implementation for Real-Time MBS Model Validation

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1. Introduction

In the development process of a complex product, such as those in the automotive industry, multibody (MBS) models are now widely employed [1]. Cost reduction and shorter development time are some of the most relevant contributions of multibody techniques. MBS models can be built either using specific tools and methods that guarantee flexibility and efficiency, or using commercial MBS software allowing greater ease of use. In the literature, several self-developed MBS models for full-vehicles are available [2]–[6]. To validate the accuracy of vehicle models, a methodology, employed for the validation of the NADSdyna model of the National Advanced Driving Simulator (NADS), consists of three main phases: experimental data collection from the vehicle, data conditioning, and comparison of simulation predictions with the experimental data [7]–[9]. As measuring dynamic responses of a vehicle is not an error-free exercise, several subsystems (throttle, brake, steering wheel…) of test vehicles are often automated to improve maneuver repeatability. In this paper, an X-by-wire (or instrumented and automated) vehicle is used to automatically repeat maneuvers in order to generate benchmark data to validate a self-developed MBS model [2]. Section 2 presents the motivations for the validation of the self-developed MBS vehicle model and the associated techniques. Section 3 describes in detail the vehicle instrumentation. In section 4, experimental data of the vehicle dynamics are gathered during specific automatic maneuvers. Finally, section 5 presents the concluding remarks.

2. Motivations and techniques for the validation of vehicle models

The validation of vehicle dynamics models through field testing allows identifying with accuracy the reliability of a model [7]–[10]. In this project, this step is essential, as one of the objectives is to study the accuracy of the MBS formulation employed to build the vehicle model. The experimental data (sensor information, actuator inputs) recorded during automatic maneuvers must be carefully chosen so that the maneuver can be properly repeated in the simulator.

3. Description of the vehicle prototype instrumentation

The X-by-wire vehicle prototype considered within this paper has been prepared for the implementation of automatic driving maneuvers. Firstly, the vehicle prototype has been equipped with a Steer-by-Wire system [11], composed of two geared coreless DC motors. The first DC motor steers the front wheels of the vehicle following the position of the steering wheel, while the second DC motor is responsible for generating a reaction torque to the steering wheel. Next, a 5-phase linear stepper motor controls the pressure in the brake circuit actuating on the brake vacuum servo. Finally, the speed of the internal combustion engine is controlled by a conventional stepper motor coupled to the throttle valve. Table 1 lists the measured magnitudes and the sensors employed.

Table 1: measured magnitudes

Measured magnitude	**Sensor**
Vehicle accelerations (X, Y, Z)	Accelerometers (m/s^2)
Vehicle angular rates (X, Y, Z)	Rate sensors (rad/s)
Vehicle angular angles (X, Y)	Inclinometers (rad)
Wheel rotations velocities	Hall-effect sensor (rad/s)
Brake line pressures	Pressure transducer (kPa)
Steering wheel and rack and pinion angles	Encoder (rad)
Engine speed	Hall-effect sensor (rad/s)
Rack and pinion torque	Torque sensor (Nm)
Throttle position	Encoder (rad)
Rear wheel torque	Wheel torque sensor (Nm)

A complete on-board data acquisition system is in charge of sensor recording, closed-loop control of the actuators, data log and load.

4. Automatic test maneuvers and repeatability

Two different types of test maneuvers are considered to validate the MBS model. The first type involves the longitudinal dynamics of the test vehicle: straight-line acceleration and straight-line braking. The second type is used to characterize the lateral handling mode: lane-change and J-turn. The X-by-wire vehicle prototype can be driven in three different modes to perform automatic test maneuvers. The vehicle inputs can be obtained from the data of the maneuvers previously performed by a test driver, or from the data collected during predefined maneuvers, or even from the data obtained by the simulator using the self-developed MBS model. Special emphasis is placed on the repeatability of test maneuvers, as good maneuver repeatability allows for the evaluation of the experimental uncertainty, and for the reduction of unmeasurable disturbances.


Fig. 1: X-by-wire vehicle prototype

5. Conclusions

This paper first describes the motivations and the techniques to validate vehicle models. Next, in order to generate benchmark data for the validation of a self-developed MBS model, the instrumentation and the first field testing results of an X-by-Wire vehicle prototype are presented. Special attention has been paid to repeatability during automatic test maneuvers as it is crucial to reduce the effects of sensor noise and to evaluate the experimental uncertainty. Future studies will focus upon the improvement of the self-developed MBS model by comparing experimental and simulated data.

6. References

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