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MODERN TOOLS FOR VEHICLE DEVELOPMENT

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Abstract: *The development of vehicles is constantly advancing, therefore, it is required to have more sophisticated tools for the development of a complete vehicle or its individual parts. This article describes modern tools used at the Institute of Automotive Engineering in Brno for vehicle development, i.e. simulation multibody software MSC ADAMS/Car or tools for MIL and HIL testing of mechatronic systems. Furthermore, the article presents tools enabling the use of multibody models for analysing data obtained from driving tests and software for processing and analysing the measured or calculated data obtained during all phases of vehicle development.*

Keywords: Multibody models, Dynamics, MIL, HIL, Simulink, NI VeriStand, C, C++, Adams/Car, Data analysis, Vehicle dynamics testing.

1. Introduction

The development of vehicles is constantly advancing, therefore, it is required to have more sophisticated tools for the development of a complete vehicle or its individual parts. Thus, this article describes not only the commercial tools, but also the primary custom tools for the development and testing of vehicle dynamics and mechatronic systems at the Institute of Automotive Engineering in Brno.

Simulations using a detailed multi-body model significantly contribute to the development of the vehicle in the pre-prototype stages and are widely used during all developmental stages. Currently, it is possible to use one of the commercial software such as MSC ADAMS, SIMPACK, and LMS Virtual.Lab Motion (LMS DADS). Chapter 2 describes the use of MSC ADAMS software and its module ADAMS/Car.

The third chapter deals with tools used for the testing and development of mechatronic systems. Here mainly the developing custom tools for MIL and HIL testing are described. Therefore, the library was developed to assemble different configurations of vehicles and also for a vehicle simulator to test ECU prototype. These tools are continuously expanded and used for fast and parallel development of mechatronic applications in cooperation with automotive manufacturers.

After the simulation of vehicle and component testing it is required to take a test drive of the vehicle. These tests verify the function and mutual co-operation of all subsystems and also perform a synchronisation of all setting elements – the final setting. For these purposes, it is important to have a means which would simplify the data analysis, either with their effective processing or by providing quantities which are essential for the analysis processes. In many cases, these quantities cannot be measured or it is very difficult. Therefore, a method and software tools are created to effectively build a detailed multibody model which could be linked with the measured signals and calculate dynamic states of the vehicle while tested (see Chapter 4).

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The last chapter details a tool for general data processing of measurements and calculations which is used in all developmental stages of the vehicle.

2. Tools for vehicle dynamics – Adams

Through the multibody method of mechanism analysis it is possible to perform static, kinematic and dynamic simulations of individual subsystems and the whole vehicle and thus analyse the resulting properties using the virtual prototype. MSC ADAMS Car software is the world's most widely used solution in the field of linking multibody system and the vehicles dynamics theory. Modelling using this system, however, requires numerous input parameters and interdisciplinary experience. Based on the sophisticated databases of the already verified models of individual subsystems, it is possible to significantly shorten the time needed to build the basic and also more advanced analyses, while achieving sufficient robustness of calculation. To simulate the various events the predefined and also custom test rigs for axles, drivetrain and the entire vehicle are used. During driving simulations, it is possible to use a variety of standardized manoeuvres and multiple levels of feedback driver algorithm. These allow to find and analyse the situations that are the stability limit of the vehicle. Finished models offer virtual testing and analysis of the impact of the construction changes on the vehicle characteristics before the production of the physical prototype (Fojtášek, 2016). Of course, it is possible to replace the individual rigid parts with flexible bodies and the direct calculation of the deformation and tension under static and dynamic loading, or export of load states may be further used in subsequent strength and endurance calculations.

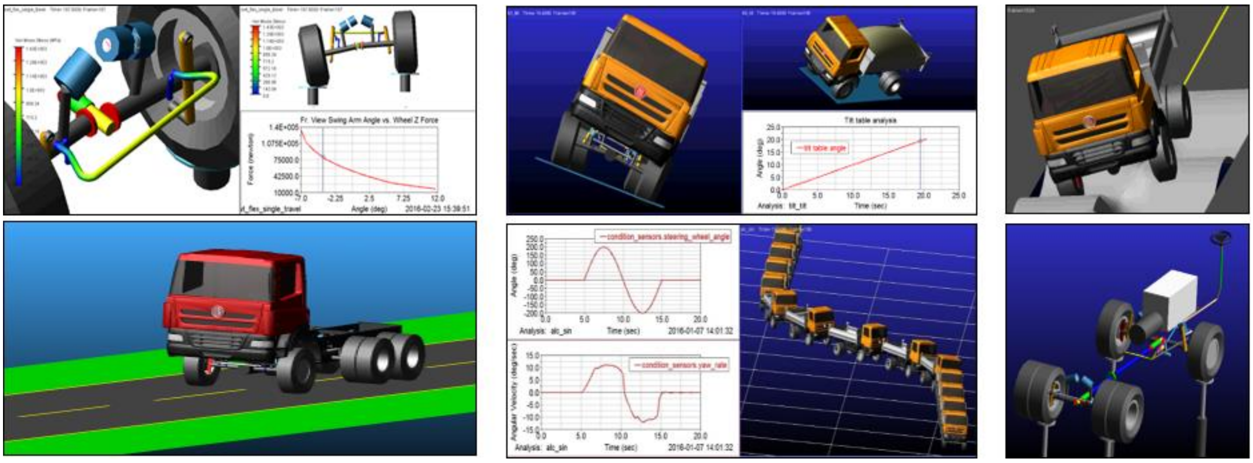

Fig. 1: Adams/Car applications.

3. Tools for development of mechatronics system - HIL

Custom applications for mechatronic systems are developed in C, C++, or in a Simulink software. To verify the design of the control algorithm in the MIL testing, own library with blocks describing individual parts of the vehicle is developed in Simulink software. More detailed description can be found in (Kučera, 2014). Users of this library can assemble the whole vehicle. This can test the vehicle dynamics, vibration and especially the different mechatronic systems. After the verification of algorithm by MIL testing, hardware for HIL testing is used. For this purpose, the National Instruments hardware NI 3110 RT is used. This device is a substitution for the control unit used for testing on a real vehicle. The control algorithm is compiled into the appropriate language and it is placed using NI VeriStand software into the hardware processor. Using the I/O interface the user can connect the necessary sensors and actuators. A sample of application is a developed mechatronic system used for automatic control of the lock differential in cooperation with the truck manufacturer. It is described by (Kučera, 2016). In the first phase of the development it is possible to test the control algorithms in the laboratory, as shown in Fig. 2 on the left, and then also on the actual vehicle. An advantage is the parallel development of the ECU prototype. Another tool is a vehicle simulator in real time described in (Kučera, 2015). It is a tool for simulation and visualization of a vehicle driving which is controlled by a real driver. This is illustrated in Fig. 2 on the right. These tools are used and can effectively and parallely develop and test the mechatronic system.

Fig. 2: HIL applications.

4. Data Analysis Using Multibody Model of Vehicle

This chapter describes the resources by which it is possible to enclose the driver – test vehicle – mathematical model into one computational loop. These resources are used during test drives to analyse the dynamic behaviour of the vehicle, its subsystems and final optimization of their settings. For this purpose, a measuring system that is able to provide all the necessary quantities for calculating the vehicle dynamic state is assembled. SAMS multibody software is also created (Porteš, 2014). Based on the 3D topology of the mechanism the software generates the model equations in symbolic form (the programming language C++), generally for solving kinematics, statics and dynamics (direct and inverse problems). In order to interconnect the measured data with the computational model, its formalism is adapted and supplemented by modelling elements, allowing the model to include forces and torques of unknown size (Porteš, 2014). Measured and calculated data are analysed, processed and animated using data analysis software TeleMatrix. This approach will get results from the measurements which are comparable in complexity and detail to the simulation calculations and to the user is comfort comparable to current multibody simulation software. Another advantage of this approach is that with the right set of measured signals, it is not necessary to include models of all subsystems, as it would be the case with conventional simulation. For example, it is not necessary to include the tire model with over 50 parameters. On the other hand, the calculation of the vehicle states could provide force effects and kinematic quantities which allow us to obtain parameters of the tire model during data post processing or to adapt the parameters to conditions corresponding to the drive test. Fig. 3 shows the principle of the method of connecting the measured values with the mathematical model.

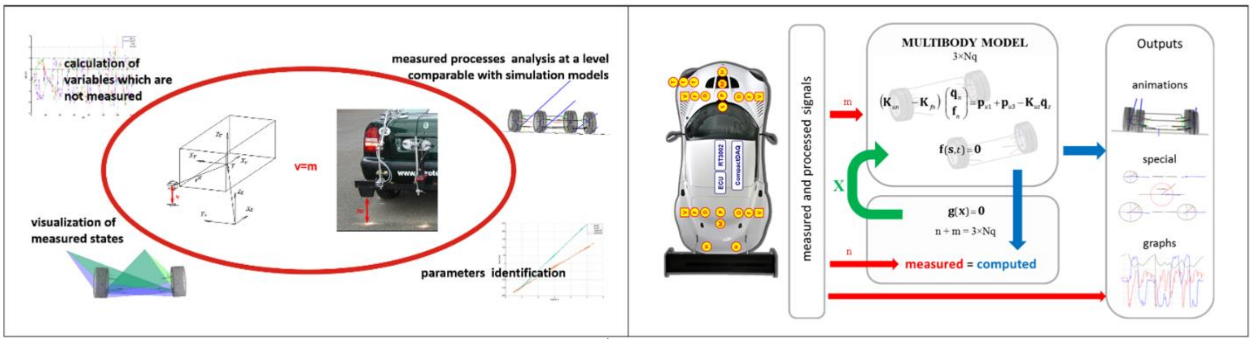

Fig. 3: The principle of linking the measured values with a mathematical model.

5. Data Analysis – TeleMatrix

TeleMatrix program is composed as an extension of Matlab development environment. The main purpose is to concentrate and interconnect various analytical tools that can then be easily and quickly applied in the analysis and processing of heterogeneous data. The program also allows to create automated procedures, which can then be advantageously applied during all developmental stages of the vehicle. It is important for comparison of the results, e.g. from partial developmental stages – the pre-prototype simulation, verification measurements of the prototype, or test drives during the final tuning of the vehicle. In addition to the wide range of traditional tools for data analysis and the ability to import from many different formats and data loggers, the program also allows to work with events, commentaries, intelligent search of conditions, compiling final reports, and an overall management of large projects.

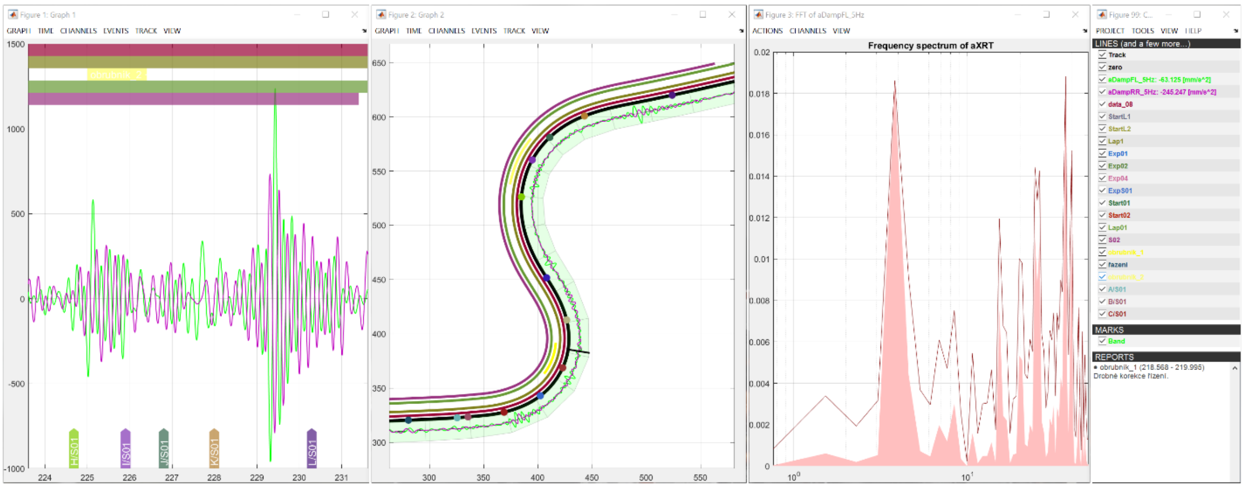

Fig. 4: TeleMatrix – example of analysed data.

6. Conclusions

The aim of all automotive institutions is to have sophisticated tools for fast and efficient development. Therefore, this article described a combination of commercial and custom made tools for development and testing of vehicle dynamics and mechatronic systems.

For the simulation of a vehicle drive and optimization of its parameters, MSC ADAMS/Car software is used, particularly in pre-prototype stages, but also in other stages if there is a need to predict the characteristics of the vehicle after the application of the proposed changes.

For MIL testing, commercial tools are extended by the libraries of the vehicle computational models. For HIL testing of the ECU, the vehicle simulator tool has been continuously extended.

To analyse the behaviour of the actual vehicles during test drives more effectively, tools which enable to utilize the multibody models for direct analysis of measured data are created.

Simple assessment and comparison of data from all individual stages of the project are then performed by TeleMatrix program which includes a number of integrated general and also specialized tools.

These contemporary tools are widely used in automotive technology and significantly contribute to rapid and sophisticated new product development.

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