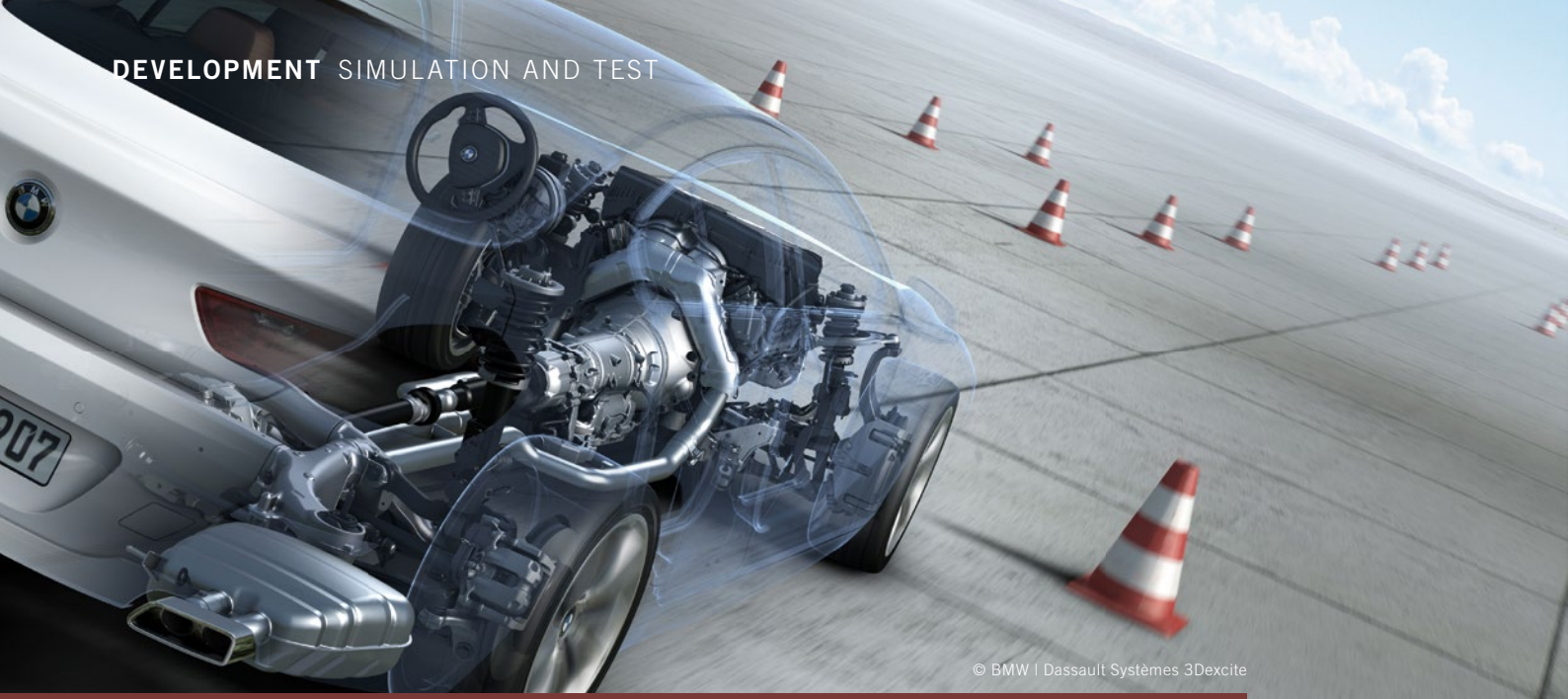

Efficient Optimisation of Handling Characteristics Using Real-time Capable Multi-body Suspensions

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Short development cycles, a great diversity of variants, increasing complexity of the systems themselves and continually rising levels of interlinking them are leading to a significantly higher calibration and validation effort, although the development resources cannot possibly increase in proportion to these requirements. This calls for methods to meet these challenges. A possible solution by IPG Automotive is provided by virtual test driving which can be used to seamlessly test and validate vehicle functions across the development process.

CHALLENGES

All OEMs have developed their own specific vehicle DNA which the driver should perceive. The desired DNA provides the basis for tuning various vehicle components and related electronic control units (ECUs). The tuning of the steering system is a crucial factor in the evaluation of handling characteristics as it plays a major role in how it feels to drive the car. The steering characteristics can be evaluated using a large number of subjective and objective criteria. To check as many factors as possible, the steering characteristics are optimised in diverse driving situations, such as comfortable cruising, urban and extra-urban driving, driving on the motorway or, depending on the type of vehicle, even on race tracks. The evaluation of on-centre steering is one of the criteria used in this context. The comparison of HiL simulation and data from a real-world vehi-

cle on a test track is shown in **FIGURE 1** using the example of an on-centre weave test with 5° steering angle amplitude. It should be noted that in this test subjective as well as objective assessment criteria can be derived for both the drift and the pull effect. The possibility of objectively formulating criteria provides the decisive basis for running the test and automating the analysis of the results in a simulation environment.

In addition to the steering system, a large number of other vehicle components have to be considered in the examination of handling characteristics. Among others, they include the tuning of the steering functions [1] in the EPS control unit, the tyre properties and the suspension design parameters [2]. The latter have a major influence on the performance of the steering system. For an early evaluation of the influence of the various components even without hardware prototypes, OEMs and suppliers frequently use simulation environments at an early stage of the development process. Therefore, due to the high level of interaction between the components shown in **FIGURE 2** regarding effects on steering behaviour, vehicle components including all the related electronic control units are integrated into the whole virtual vehicle of the CarMaker open integration and test platform as an array of virtual or real-world ECUs.

INCREASED EFFICIENCY

The conventional workflow consists of the setup and data input for the relevant suspensions (preprocessing) in a simulation tool for Multi-body System (MBS) suspensions (for example Adams or Simpack for the suspension design; IPGKinematics, for instance, for K&C suspension design). This is followed by generating look-up tables for K&C (Kinematics & Compliance) behaviour in order to subsequently use them in a full-vehicle simulation (for example CarMaker) also with real-world electronic control units. Due to the use of real-world ECUs real-time is a necessary requirement to be met by the simulation environment.

With this mapping-based preprocessing approach, it is necessary to generate a new look-up table any time a suspension design parameter, such as the position of the articulation points, is changed. In order to optimise the central requirements of real-time capability and the possibility to implement the suspension design parameters in a tool without the preprocessing step IPG Automotive has developed MBS suspensions for the CarMaker open integration and test platform [3], **FIGURE 3**.

Using the new approach it is possible in CarMaker to comprehensively investigate suspensions in a tool and to obtain detailed results regarding the interaction in the full-vehicle context at an early stage so that decisions for the further development process can be made. The real-time capable suspension models were implemented based on Mesa Verde (Mechanism, Satellite, Vehicle and Robots Dynamic Equations), a system developed by Prof. Dr.-Ing. Jens Wittenburg and Dr.-Ing. Udo Wolz at the Karlsruhe University [4]. As a result of the computer processing power that is available today and optimised modelling, the MBS suspensions are run in real-time in CarMaker. Available suspensions are the McPherson, **FIGURE 4**, the McPherson extended and the fourlink suspension. With CarMaker Release 5.0 the fourlink extended, twistbeam, twistbeam extended and double wishbone suspension types will additionally be available.

Investigations have shown that the McPherson front suspension in combination with a fourlink rear suspension can be calculated on a standard PC in >1.8 times real-time. By using these suspension models the traditional workflow can be made more efficient as time-consuming process steps, such as the continuous creation of new look-up tables when a design parameter changes, is omitted as illustrated in **FIGURE 5**. In the new process, data input for the suspension in CarMaker is performed just once, which can be done by transferring parameters from other tools as well. Afterwards diverse suspension design parameters (such as the articulation points or the stiffness of the mounts) can be conveniently changed in the same tool and additional suspension parameters can be monitored directly during the simulation and saved in the same global simulation results file.

Because different tools are no longer required for optimising the suspensions and that the test automation available in CarMaker (Testmanager) is used instead for this purpose is another advantage.

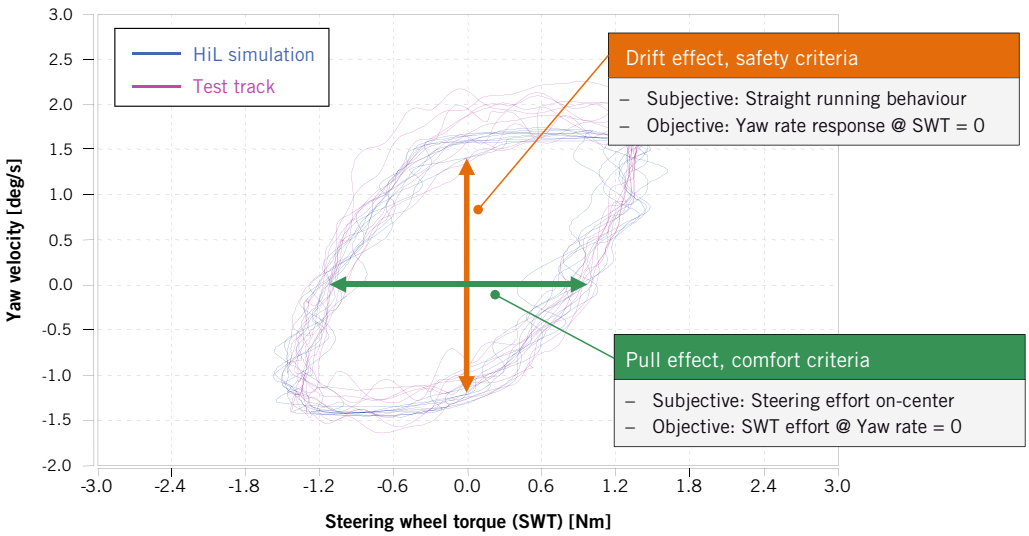

FIGURE 1 On-centre weave test

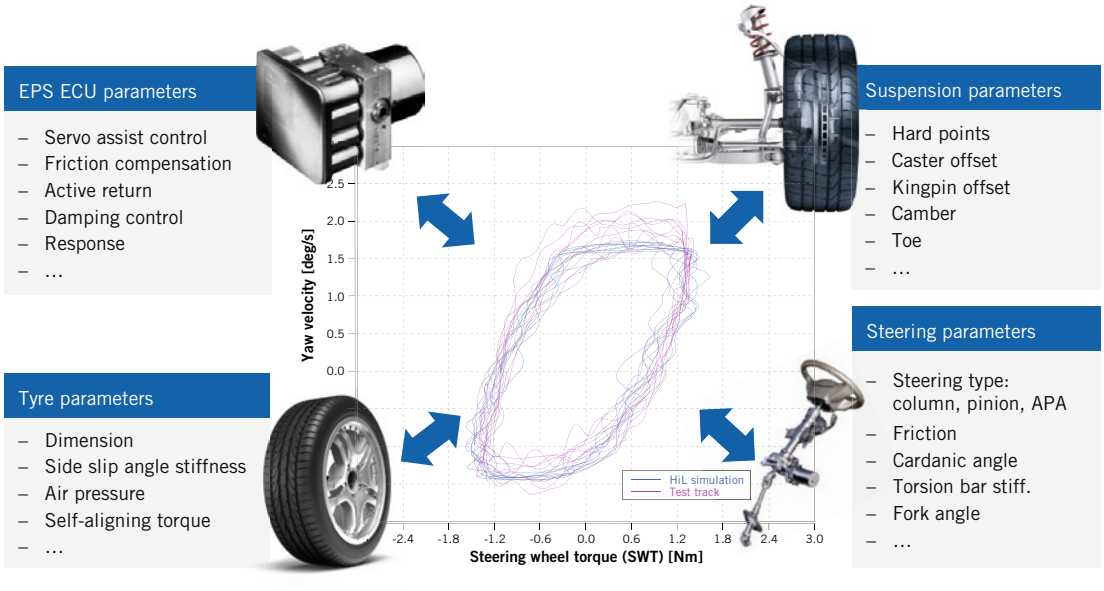

FIGURE 2 Parameters that influence the steering system

Furthermore, in Testmanager it is possible to formulate the objective evaluation criteria mentioned at the beginning of this article and to analyse them in an automated process, as well as to document the results in the form of configurable reports. Additionally, in conjunction with commonly used Design-of-Experiment (DoE) tools, CarMaker can be used for automated optimisation.

EXEMPLARY USE CASES

As stated above, the suspensions play a central role in optimising steering characteristics. Beyond Model-in-the-Loop (MiL) and Software-in-the-Loop (SiL), CarMaker can also be used on HiL test benches – and even on steering test benches with a real-integrated complete steering system if necessary – so that its seamless use across the entire development process is possible.

The investigation of controller robustness against control signal faults (as conceivable in the case of EPS and other systems) is another typical use case for real-time capable MBS suspensions. Such faults, for example, may occur due to changes made to the suspension when the ESP system is to be modified for use in other vehicle variants. Furthermore, by means of the real-time capable multi-body system suspension, steering systems can be evaluated on driving simulators. Irrespective of the analysis of the suspension parameters for the suspension design the possibility of using the more realistic, real-time capable multi-body suspensions plays a major role in another area as well, namely the production of images, animations and films using CGI (Computer Generated Imagery). The CarMaker open integration and test platform, for instance, is utilised by Dassault Systèmes 3Dexcite in order to allow exact movement manoeuvres to be used with the best possible optimisation from CAD-based 3D master models for product development applications.

VISUALLY EXPERIENCE

Within the scope of the development process highly realistic 3D visualisation is particularly helpful for modelling the correlations of geometry and function in a visible and more comprehensible manner. For the photo-realistic representation of the individual components in CarMaker, 3Dexcite Deltagen visualisation software is used. The use of the available CAD data enables a detailed examination down to the level of individual components (solids such as bodies or flexible components like bushings).

The integration of the Deltagen Real Drive visualisation solution as an interface in CarMaker provides the basis for the virtual driving simulation so that the development process turns into a tangible and emotional product experience for all the parties involved. The realistic 3D simulation of the vehicle and traffic within an immersive environment supports the efficient presentation of current states in production development projects and validation in the context of the driving situation. The vehicle, the wheels, the bodies and the bushings are linked from the simulated multi-body system suspension directly with the design data and the scenario to be tested is simulated with photo-realism and physical correctness. This allows technical correlations and interactions in the whole vehicle, particularly by means of the high-end 3D visualisation, to be presented in a way that is easier to

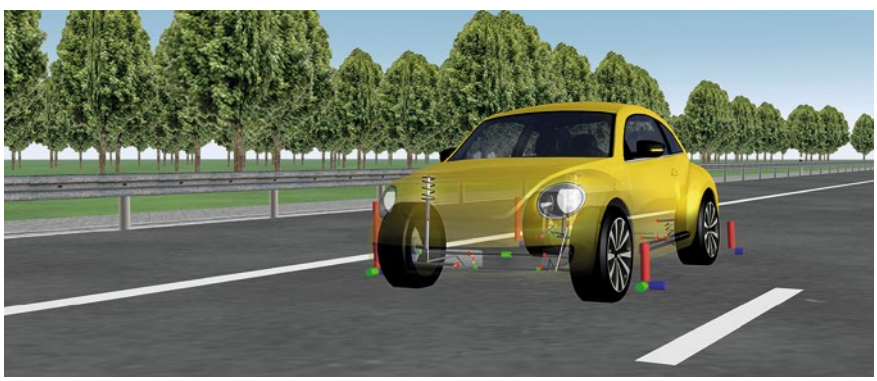

FIGURE 3 Real-time capable multi-body system suspension in CarMaker

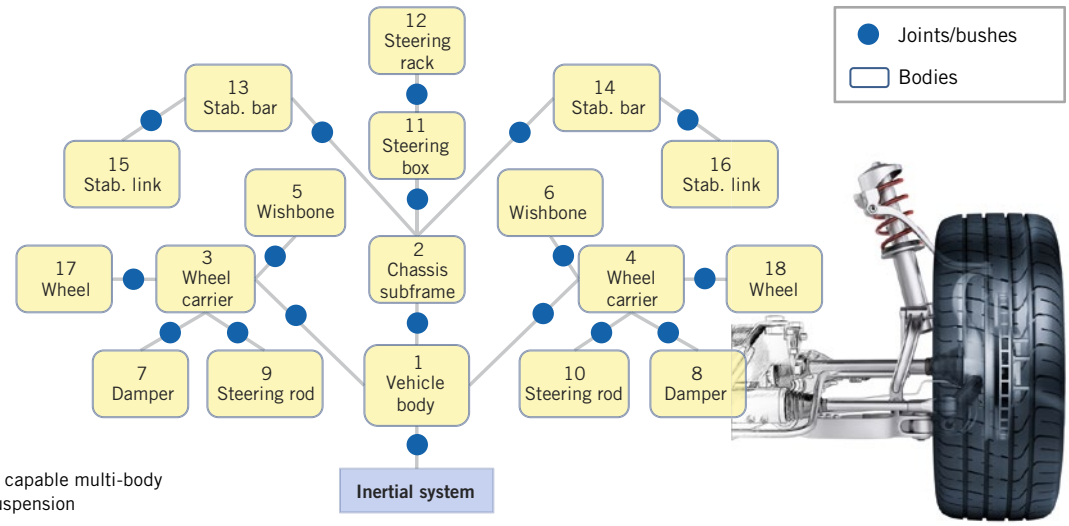

FIGURE 4 Example of a real-time capable multi-body suspension: McPherson front suspension

comprehend by decision makers and product managers. Parameters directly changed on the suspension, for example, can be subjected to a direct comparison of selected simulation results and by means of animation be compared directly in the whole vehicle. In practice, a VDA lane change test as depicted in the cover-picture is a commonly used vehicle dynamics manoeuvre in order to validate the stability of the passenger car in the dynamic limit range.

SUMMARY

Up to now, detailed simulation of multi-body suspensions and real-time simulation have been totally separate domains. By means of the developed MBS suspension models in CarMaker a more efficient performance of vehicle dynamics evaluations in the whole vehicle is now being offered. Likewise, it is possible to efficiently calibrate and validate entire vehicle components, such as the steering system including the EPS control units, assisted by extensive manoeuvre catalogues, with powerful test automation. The use of real-time capable multi-body system suspensions can thus counteract the growing development effort and, at the same time, enables both an efficient optimisation of the steering system and testing of a complex full-vehicle array. The investigation of how steering characteristics are affected by other vehicle components and their control systems can be performed quickly, early and without prototypes across the entire development process (MiL-SiL-HiL) in a single tool.

REFERENCES

[1] Reimpell, J.; Betzler, J.: Fahrwerktechnik: Grundlagen. 4. völlig überarbeitete Auflage, Würzburg: Vogel-Buchverlag, Kapitel Lenkung, pp. 275-316, 2000

[2] Wittenburg, J.: Dynamics of Multibody Systems. 2nd edition, Heidelberg: Springer-Verlag, 2008

[3] Schmidt, S.; Schmidt, E.; Henning, J.; Schick, W.: Optimization of vehicle handling performance using a full vehicle model with multibody system (MBS) suspensions in multiple real time – applying the DoE method. JSAE, Paper No. 20140225, 2014

[4] Wolz, U.: Dynamik von Mehrkörpersystemen. Theorie und symbolische Programmierung. VDI-Fortschritt-Berichte, VDI-Verlag, Düsseldorf, 1985

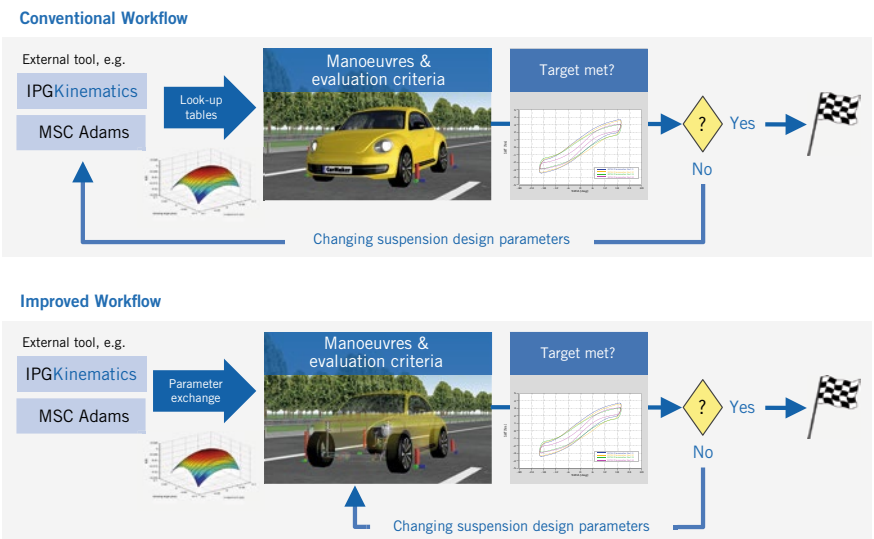

FIGURE 5 Comparison of the conventional and improved workflow