A 'game changer' for chassis development

Integrated test and simulation enables objective quantification of design changes, finds **Siemens**

With continuously shortening development cycles, the importance of early simulation is increasing year over year. In addition, and in support of simulation, testing and validation needs to be carried out with the highest possible efficiency.

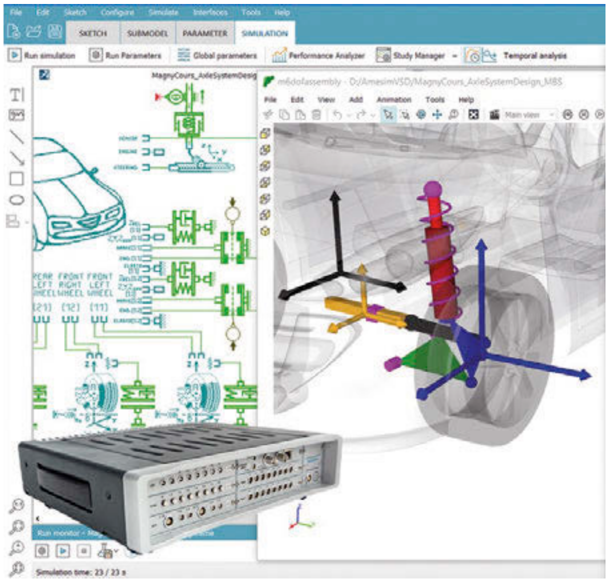
This calls for an integrated test and simulation solution for vehicle development. The Simcenter portfolio combines the best of testing and simulation. Test-based solutions identify and drive simulation models for validation and analysis of functional performance (test for simulation), while simulation models maximise the testing capabilities in terms of measurement robustness, precision and detail (simulation for test).

On both the chassis and full vehicle performance level, Simcenter Engineering experts deploy model-driven test solutions. Using models of various complexity, the engineering specialists can speed up the testing process (efficiency) and enhance the testing by enabling higher precision and increased robustness of the test results (quality). The models that are used to drive this enhanced testing can range from detailed multi-body simulation, to simplified vehicle representations such as the bicycle model.

The Simcenter Tyre team develops tyre testing methods to identify/drive simulation models of tyres for use in full vehicle simulation for different performance attributes such as vehicle dynamics, control system development and comfort. The methodology delivers models that fit the requirements and improve the correlation between simulations and vehicle tests.

Chassis & full vehicle performance

To consider chassis development in the early design stages or to get insights in vehicle performance, manufacturers need to step away from the more conventional testing approaches. Simcenter Engineering uses model-driven test approaches for the validation and analysis of dynamic performance. They identify chassis loads and/or chassis motions next to the classic vehicle performance characterisation at the CoG level. As objective characterisation is available at the axle level, and even the chassis component level, decomposed key chassis contributors can be quantified at the full vehicle level.



ABOVE: Simcenter can enhance track testing through model usage

Using the decomposition, the expert can see how the performance changes, for example gaining understanding of the difference at the centre-of-gravity level when using localised responses. This solution provides engineers with the insights necessary to understand the impact of design variations, support definition of objective metrics for target setting and, moreover, to enable them to link objective observations to subjective perceptions.

The use of models to drive these testing approaches ensures that testing is faster and more efficient, while fewer sensors are required to obtain the required test results. Another major advantage is the achieved robustness and precision in test output. These qualities offer benefits in challenging boundary conditions, such as on-centre behaviour. Due to the low (lateral) excitation levels, the classic test approaches can have limitations in terms of providing robust and precise objective characterisation of vehicle performance. This is related to limited vehicle response amplitudes with respect to measurement noise or sensor drift. As a result, design iterations are often based on experience rather than objective metrics.

In the example as demonstrated in Figure 1, vehicle testing is done at various levels of lateral acceleration. This example illustrates two challenges when considering on-center behaviour. Firstly, the vehicle response to different levels of steering input is non-linear, especially when considering small steering inputs. This is relevant for both objective performance characterisation as well as the link to the subjective appreciation.

Secondly, objective characterisation at low response levels is difficult, which is demonstrated by the large measurement variation, and the limited robustness of the test results.

Simcenter Engineering experts integrate the use of simulation models to enable testing also in challenging boundary conditions. This can be done via two approaches: by using multi-body-models to identify the chassis

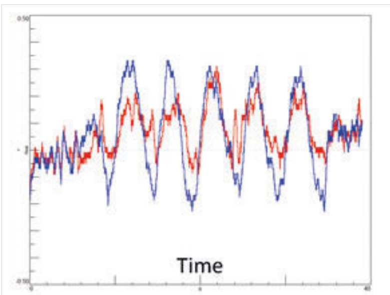
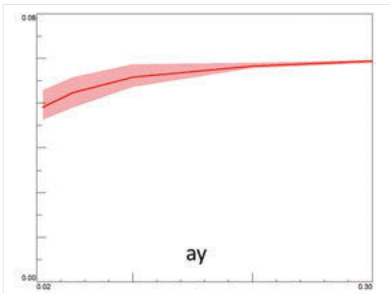
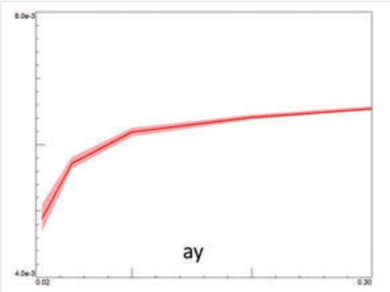


FIGURE 1A (LEFT): Roll angle measured at a low level of lateral acceleration, reaching the limitation of the sensor resolution

FIGURE 1B (RIGHT): Roll angle as function of lateral acceleration





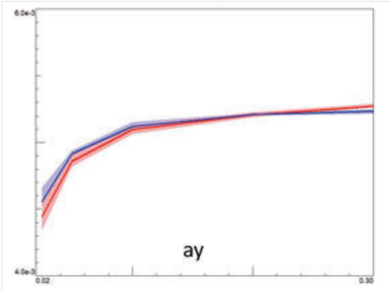


FIGURE 2A (FAR LEFT): Response at the axle level as a function of lateral acceleration capturing non-linearities and enhancing test robustness, using simulation and testing

FIGURE 2B (LEFT): Response at the axle level as a function of lateral acceleration capturing design changes at low response level for base (red) and modified (blue) conditions

loads with high precision as well as high robustness, even at low response levels; or by applying simplified vehicle models to drive the identification of the chassis motions, as illustrated in Figure 2.

The result in Figure 2 demonstrates that this approach allows testing with high precision, even at low response levels, as the measurement variation is significantly lower compared to classic test approaches. Next to that, the non-linearity in vehicle performance, clearly present when moving to small steering inputs, is objectively characterised in a robust approach. This enables engineers to accurately quantify the (changing) vehicle performance and understand the role of the axle or chassis component in view of the full vehicle behaviour.

Model-driven test solutions provide OEMs with a powerful testing process, even with boundary conditions as challenging as on-centre behaviour. The acquired response quantities help users to understand vehicle dynamics performance changes caused by design variations, at the full vehicle level as well as on individual axles or chassis components. This capability allows users to define advanced metrics in support of vehicle development, considering both objective characterisation and subjective assessments.

Tyre modelling in a full vehicle simulation context

The Simcenter Tyre solution provides an integral tyre modelling approach to provide accurate and cost-efficient tyre models for vehicle dynamic simulations. The solution not only comprises the tyre model development, but also tyre testing services for model parameterisation and knowledge-intensive engineering projects. This approach provides customers with a tyre modelling methodology rather than just a tyre modelling software tool.

In the field of tyre modelling, an integrated test and simulation approach is essential. On the one hand, tyre tests are used for model parameterisation and significantly influence the final tyre model performance. On the other, tyre models are used in vehicle dynamic simulations which are often validated by means of vehicle tests.

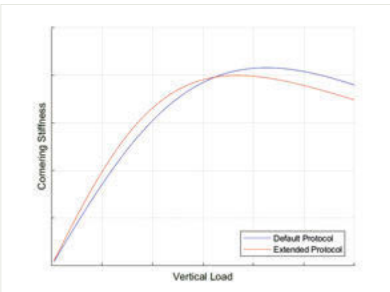
For tyre test and model parameterisation, there are two important requirements. Firstly, several tyre conditions and states are not modelled, but instead inherited from the tyre measurements. During tyre testing, conditions such as the road surface properties, tyre thermal state, and tyre wear need to be manually tuned to mimic the desired full vehicle operating conditions. To increase the applicability of the Simcenter Tyre models, the 2020.2 product release will include the tyre thermal and velocity dependency.

Secondly, for conditions such as side-slip angle, inclination angle and vertical load, the tyre testing protocol should cover the complete operating envelope of the final full vehicle application. By adding tests for specific operating areas, tyre model accuracy can be increased.

In our example, the on-centre handling application is considered with side-slip angles and camber angles that remain very small. The baseline Simcenter Tyre testing protocol includes tyre tests that determine the tyre's lateral slip characteristics over a range of +/- 12° of slide-slip angle. Due to the significant tyre forces during this test, tyre heat build-up is inevitable and will alter tyre performance in the low-slip region. To avoid an equal numerical weight over the complete side-slip angle range, adding dedicated low side-slip angle measurements needs to be considered. This keeps the tyre in the representative operating condition and adds more fidelity in the low-slip region, which is of importance for on-centre handling applications.

The example in Figure 3 demonstrates the resulting tyre model characteristics of one tyre variant, of which the parameters were identified based on the default tyre testing protocol and the default tyre testing protocol, extended with dedicated low-slip measurements.

Two key tyre characteristics are compared; cornering stiffness as a function of the vertical load, and offset of the lateral force at zero slide-slip. Both characteristics show a new level of accuracy when deploying the testing and parameterisation method. While at OEMs, the cost for tyre testing increases and the high-slip model accuracy slightly deteriorates, the tyre test and model parameterisation methodology showed excellent results at a major passenger car manufacturer, significantly improving the correlation between simulations and vehicle tests.



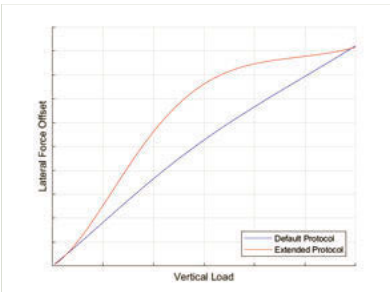


FIGURE 3A (FAR LEFT): Modelled cornering stiffness characteristic with parameters based on default and extended testing protocol

FIGURE 3B (LEFT): Modelled offset of the lateral force at zero slide with parameters based on default (green) and extended (blue) testing protocol

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