FTire and ASM – Sophisticated Models for Real-Time Vehicle Dynamics Simulation

FTire/realtime: Detailed Tire Physics for HIL and Driving Simulators

The tire is the most important and, at the same time, the most complex vehicle suspension compo-nent. As a consequence, tire simulation today requires more than just a mathematical approximation of some steady-state deflection-based and slip-based force/moment characteristics on flat surface, no matter if the simulation is part of a detailed computer-aided engineering (CAE) process chain or if it is used in real-time environments. Rather, current offline and HIL simulation tools for new steering and suspension control systems, drive concepts, and vehicle architectures have to include a versatile, robust and multipurpose tire model that can be used in 'classical' handling and ride comfort tests, and also together with highly dynamic suspension, drivetrain, or road-induced excitations.

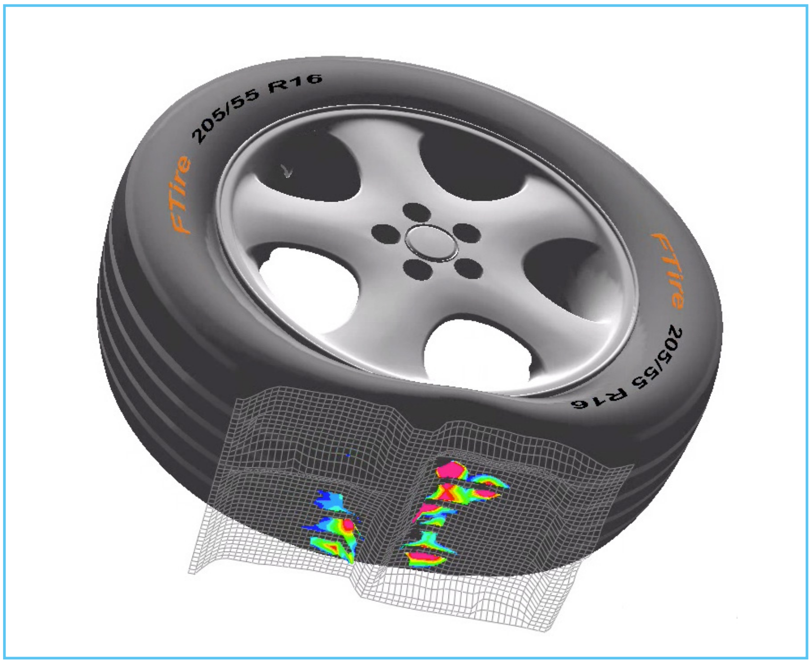

Figure 1: Workflow for the electrical measurement and validation of electrochemical storage systems.

Preparing for Real Time

To meet these requirements, the state-of-the-art physical tire model FTire (see *www.cosin.eu*) has recently been enabled for use with HIL and driving simulators. To this end, the model has been modi-fied as follows:

- Rarely used, time-consuming model extensions like tread wear models, flexible rim models, soft soil models, and air cavity models are deactivated by default
- The animation window and time-consuming computation of extra output is deactivated, but is available offline
- Solver numerics, based on partially implicit integration, have been optimized
- The default temporal and spatial resolutions have been lowered slightly, but both are still scalable to make best use of available computing resources
- A highly efficient multithreading technique, based on the parallel computation of all 2, 4, 6 or more tire instances has been implemented
- A fast User Datagram Protocol-(UDP-) based bidirectional communication for data exchange with the calling vehicle model solver is used

Tire Characteristics in Real-Time Simulations

The resulting tire model is completely real-time-capable and yet fully physics-based. Its most im-portant features are:

- On-the-fly variation of inflation pressure, tread depth, tread temperature, and local road fric-tion properties
- Account for radial and tangential non-uniformity, static and dynamic imbalance, run-out, tread gauge variation, conicity, and ply steer
- Realistic simulation of pressure drop, tire puncture, and run-flat behavior
- Accurate parking torque during standstill or slow rolling
- Short-waved road irregularities and single high obstacles
- Versatile and highly accurate road attribute description via regular grid road (RGR) models
- High-frequency brake pressure variation at all rolling speeds
- Tire simulation for all kinds of vehicles: cars, light vans, trucks, buses, motorcycles, scoot-ers, tractors, dump and mining trucks, aircrafts and more
- Frequency range of validity up to 200 Hz, yet perfectly working together with simplified, look-up-table-based suspension models
- Exactly the same data file as used by the standard FTire version
- Large number of powerful post-processing and analysis tools

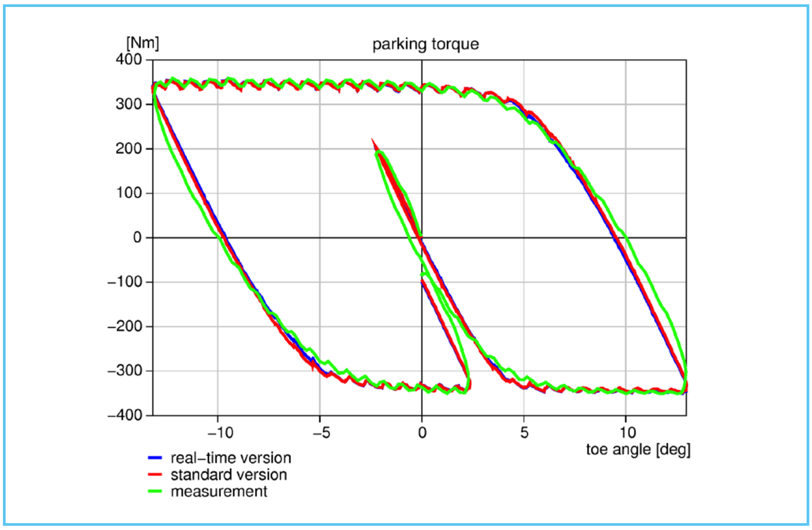

Fig. 3: Typical parking simulation results of a real-time simulation with ASM Vehicle Dynamics and FTire/realtime compared to the standard FTire approach and real measurement data. The combination of ASM Vehicle Dynamics and FTire/realtime lets developers investigate the stick-slip effects during realistic closed-loop maneuvers without loss of accuracy.

Simulation Setup

To investigate tire characteristics under the conditions of real driving scenarios, the simulation must include models for the vehicle dynamics, driver, and environment. The ASM Vehicle Dynamics Model by dSPACE provides open Simulink models for the real-time simulation of vehicle dynamics behavior in a specified environment. ASM Vehicle Dynamics is typically used on a dSPACE Simulator or dSPACE SCALEXIO® system to perform hardware-in-the-loop tests on electronic control units (ECUs), but it is also used with offline simulation platforms for early validation during the design phase of controller algorithms. The model supports all the relevant phases of the model-based de-velopment process. ASM Vehicle Dynamics includes simulations from passenger cars to trucks and can be combined with all other ASM models, such as ASM Trailer for trailer simulation, ASM Engine for virtual vehicle simulation, and ASM Traffic for ADAS applications.

Application Example: Steering Simulation with or Without a Test Bench

When combined with FTire/realtime, ASM Vehicle Dynamics is ideal for investigating vehicle handling and ride comfort in real-time environments such as dSPACE SCALEXIO® where slip-based tire mod-els fail. A typical example is testing electric power steering (EPS) controller behavior. The combina-tion of FTire/realtime and ASM Vehicle Dynamics makes the simulation of steering model activities in standstill conditions or during parking maneuvers realistic. For vehicle dynamics simulation, many parts of the chassis can be combined in look-up tables. How-ever, this is not useful for steering systems, because different EPS variants have to be simulated with their respective elasticities and friction elements. The ASM steering model displays the steering components as modules and has up to four degrees of freedom, depending on the configuration. The individual components, such as the steering wheel and upper steering column, the lower steering column and rack and pinion, and the EPS system, are coupled kinematically via Cardan joints and gear ratios, and elastically via spring-damper elements. The influence of friction is simulated using parameterizable friction elements. The variables that are needed for running the EPS controller are provided as simulated sensor variables. The model has the interfaces required for the individual EPS variants and their test systems.
The combination of FTire/realtime and ASM Vehicle Dynamics runs on a SCALEXIO® multicore sys-tem. Due to the complex computation in FTire/realtime, one processor core is reserved for each tire. The tire and vehicle models communicate via hypervisor technology. For this, a bare-metal hypervisor (from Real-Time Systems GmbH) is used in privileged mode. This ensures high performance and low latencies in the communication with the I/O.
EPS controller test systems exist in different levels of complexity. Depending on the degree of inte-gration of the mechatronic systems, the test systems range from pure electronics testing to mechani-cal test benches including a steering column and rod. Two examples are shown below. The ASM Ve-hicle Dynamics Model provides interfaces for all the system integration levels.

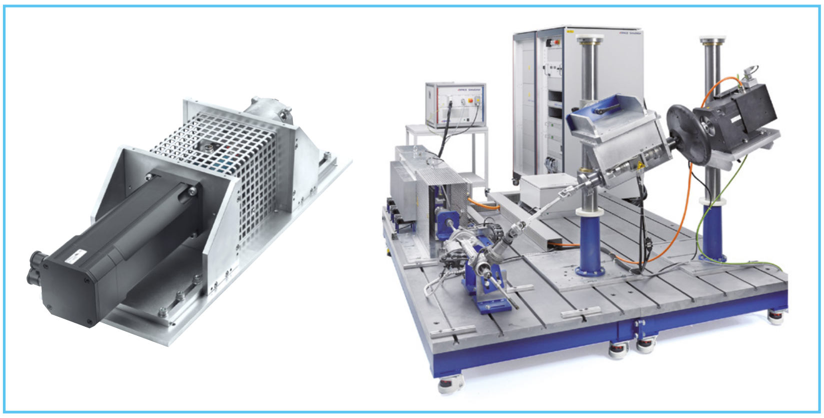

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Fig. 2: Simple test setup for EPS systems with separable EPS motor (left), and a complete steering test bench for steering systems with an integrated EPS motor (right).