Virtual Endurance Testing on the Test Bed

When prototypes are scarce, validation effort increases, and variants need to be validated efficiently, traditional test methods are reaching their limits. A major German OEM is using CarMaker Testbed to integrate endurance tests into a virtual vehicle environment on a powertrain test bed. This creates a reproducible, accelerated process for endurance testing – ready for use long before first vehicles are available for road tests.

Endurance testing is indispensable for validating powertrains in terms of function validation as well as lifespan and robustness evaluation. However, due to the increasing complexity of state-of-the-art powertrain architectures and a growing number of variants, conventional approaches are put under pressure. Available experimental vehicles can oftentimes not sufficiently model all relevant configurations on the road or test track. At the same time, the demand for timely and scalable validation considering realistic customer usage is growing.

In the context of an implemented OEM customer project, the aim was to perform the complete customer-oriented road endurance test on a test bed with real-world conditions as well as full control of vehicle behavior, driver models, route topology, and traffic density.

The basis for this was CarMaker Testbed: The system connects real test bed technology with a complete virtual vehicle environment in real time, see Fig. 01. This enabled the simulation of a complete endurance test – with the real powertrain on the test bed and a virtual environment including vehicle model, driver, traffic, and infrastructure. The presented use case hence created a highly flexible test system which was tailored precisely to the requirements of the customer project.

The connection is based on a real-time interface between CarMaker and test bed automation. The vehicle model performs all dynamic tasks in the virtual world. CarMaker calculates vehicle motion, wheel loads, and traction relations based on the drive torques from the test bed. The wheel speeds are fed back to the test bed control live and separately for each wheel, including braking forces, friction torques, and rolling resistances. Because the side shafts of the powertrain represent the system boundary of the free body in the virtual vehicle model and on the test bed setup, any test bed configuration can be integrated: from two dynamometers for front-wheel or rear-wheel drive to up to four fully synchronized units for all-wheel drives. The rotational speed control takes place via target values that are specified directly in CarMaker from vehicle simulation.

The course of the road, ambient conditions, driving behavior, and traffic scenarios can be fully configured, see Fig. 02. The project used real route data, for example based on HERE HD maps or OpenDRIVE data that can be automatically imported into CarMaker, as a framework. Realistic and precise modeling of route characteristics such as crossings, speed limits, and local traffic regulations is possible. Complex routing, such as mountain drives or urban commuter traffic, can be simulated quickly and easily as well.

Overview

Customer

Major OEM

Country

Germany

Products

- **CarMaker Testbed**
- **Xpack4**

Challenge

Early and scalable validation of all relevant vehicle configurations based on realistic customer usage

Solution

Execution of endurance tests on the powertrain test bed, integrated into a virtual vehicle environment

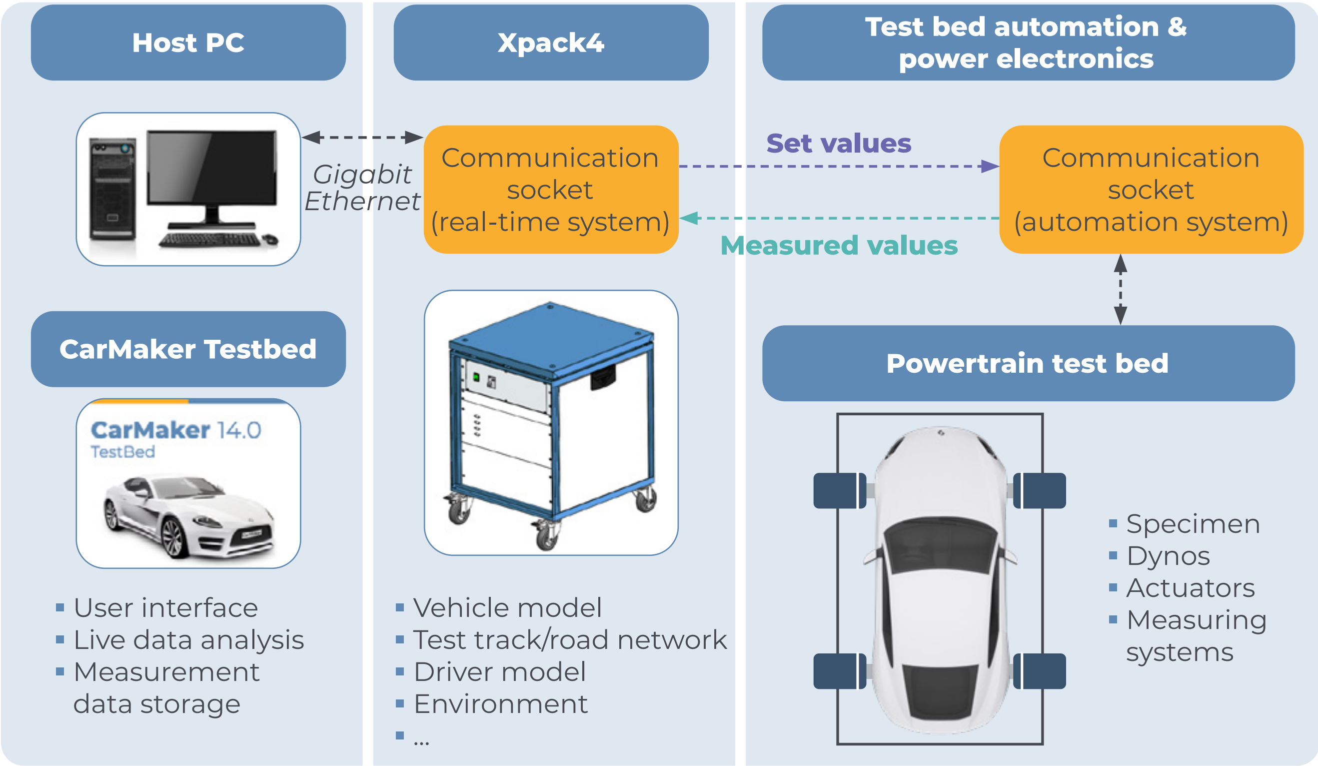

Fig. 01: Example setup of a powertrain test bed

The flexibility also shows on driver level: Different driving styles, from cautious long-distance drivers to dynamically accelerating sports car drivers, can be parameterized in detail. All parameters such as reaction behavior, lateral and longitudinal acceleration, or lane following can be measured objectively and reproducibly. In the customer project, testing personnel chose the option to perform dynamic changes during the test run: acceleration and deceleration limits were adjusted live depending on the lane, traffic density, or test goals to ensure realistic road testing.

For the traffic around the ego vehicle, a local and stochastic model is used. Instead of a global scenario, the simulation focuses on an adjustable environment radius which significantly lowers the number of actively calculated traffic objects, while keeping consistent realistic behavior in the immediate environment of the ego vehicle. Traffic objects are added or removed dynamically to specifically increase or lower the traffic density, for example to model city traffic, construction sites, or free roads.

In practical use, the project showed tangible benefits for testing personnel: Test runs can be fully automated and scenarios can be reproduced in any constellation. Both dense traffic with traffic jams as well as free roads can thus be modeled in the same virtual road section. In 24/7 operation, long-distance tests can be performed efficiently, monitored seamlessly, and adapted immediately if necessary. Load spectra, endurance values, and relevant KPIs are already available during testing and can be processed directly with existing evaluation routines, such as in MATLAB or Python. Using other tools from IPG Automotive or open interfaces, all data can be analyzed and documented in a structured way, including the generation of automated reports. Test preparation, performance as well as evaluation and analysis can therefore be performed in a much shorter time frame, increasing data maturity in early development stages and creating new degrees of freedom in endurance testing. At the same time, results can be evaluated directly at the control station, allowing for conclusions that can immediately be fed back into the running test process.

Finally, this approach enables a seamless transition between the development stages from model-in-the-loop (MIL), software-in-the-loop (SIL), hardware-in-the-loop (HIL) to powertrain-in-the-loop (PIL). Validation can start at early development stages already, independently from vehicle or road availability. This lowers preparation time, increases test depth, and frees up real testing capacities.

In the scope of the described project, this methodology was successfully implemented. The real-time connection of the experimental vehicle with vehicle simulation met all requirements to a practical endurance test. It allowed the customer to validate data statuses or calibration solutions for series release and to adapt them for individual model derivates as well as to test new components in a targeted manner regarding functionality and reliability.

Endurance testing on the test bed with CarMaker Testbed served the release of the powertrain for a defined production series. Degradation and damage analyses as well as thermal and electric evaluations were performed flexibly at different points in time during endurance testing or when reaching defined mileages on the powertrain. The described PIL test environment provided a resilient, efficient test procedure on the way to series release of the respective powertrain.

Summary

CarMaker Testbed combines real test bed engineering with a virtual vehicle environment and thus creates a practical alternative to traditional endurance testing on the road. Complex driving profiles, realistic traffic conditions, and driver-specific driving behavior can be modeled flexibly on the test bed. In practical use at the OEM, this created reproducible test conditions in continuous operation that are independent from weather, traffic, or driver influence. The result is a seamless and efficient validation process, which allows complex scenarios to be modeled in a much faster and targeted way compared with real road endurance tests.

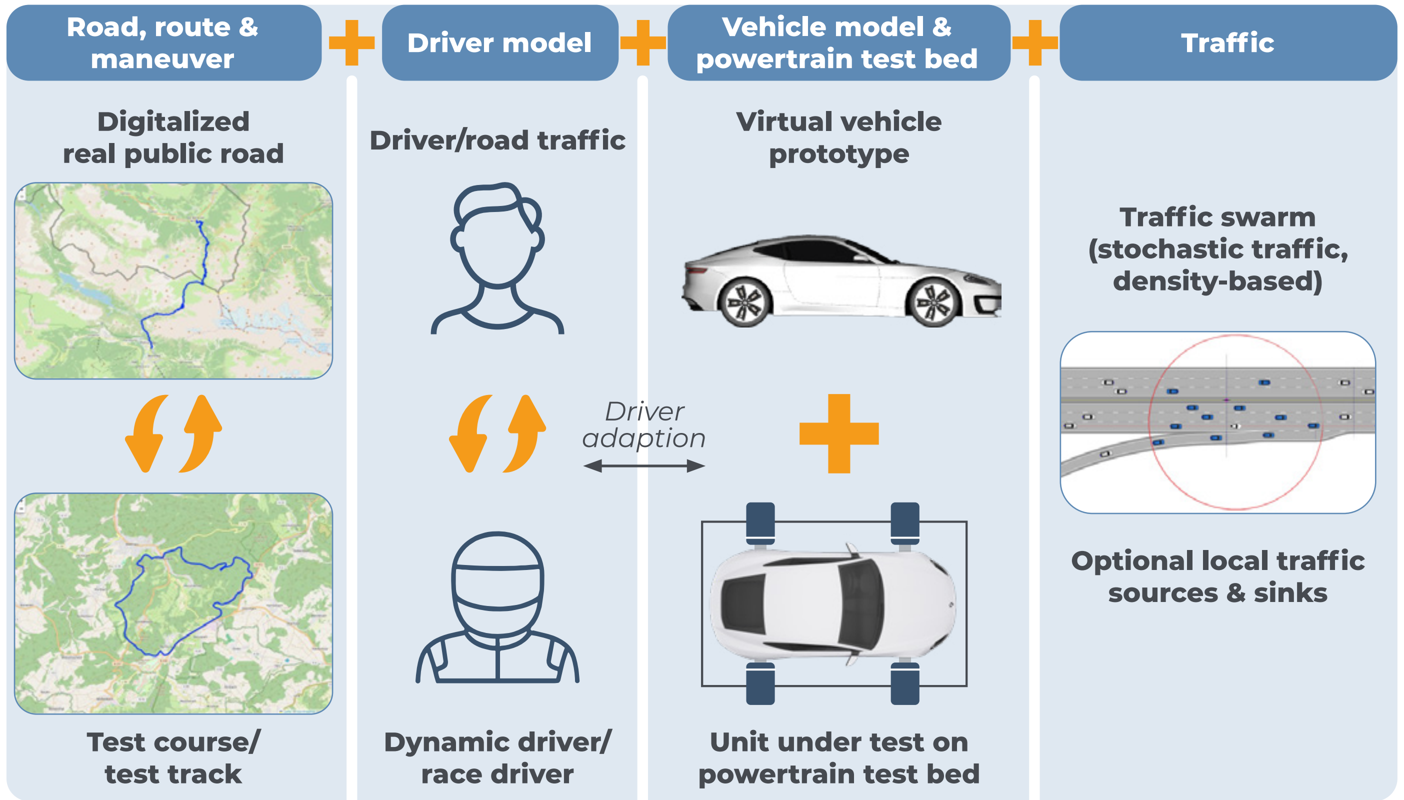

Figure 02: Integration of the course of the road, ambient conditions, driving behavior, and traffic scenarios