

# Advanced Simulation on the Testbed

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For the development of complex control algorithms and strategies the engine and drivetrain testbed offers a number of advantages over the development in the prototype vehicle. The paper discusses the application of modern simulation technologies during the online simulation and the advanced testbed simulation in an open environment. The integration of hardware-in-the-loop testing together with vehicle and transmission simulation on the testbed allows to speed up the optimization of fuel consumption, emissions and driveability in an early stage in the development process. The available software tools are presented and application examples are given.

## 1. Introduction

Modern engine and drivetrain testbeds are more and more used for the development of complex control algorithms and strategies, which should optimize the fuel consumption, emissions and driveability of the vehicle. For the development of those strategies the testbeds offers a number of advantages over the development in the prototype vehicle:

- Standard simulation models are already available on the testbed.
- A large number of measurement devices can be applied directly to the unit-under-test.
- The unit-under-test can be controlled directly via throttle and clutch actuator and gearshift robot.
- The electronic control units for engine (ECU) or transmission (TCU) can be accessed directly via ASAP 3 or CAN bus interfaces from the testbed computer.
- Software for test automation, visualization, recording and post-processing is available on the testbed.

## 2. Offline Simulation

In the initial phase of the development process the future vehicle will be designed in a complete offline simulation. The performance of the vehicle will be evaluated with respect to driving performance, emission and fuel consumption.

AVL offers with the offline simulation software CRUISE an excellent tool for this task and allows to move on quickly to the next development phase.

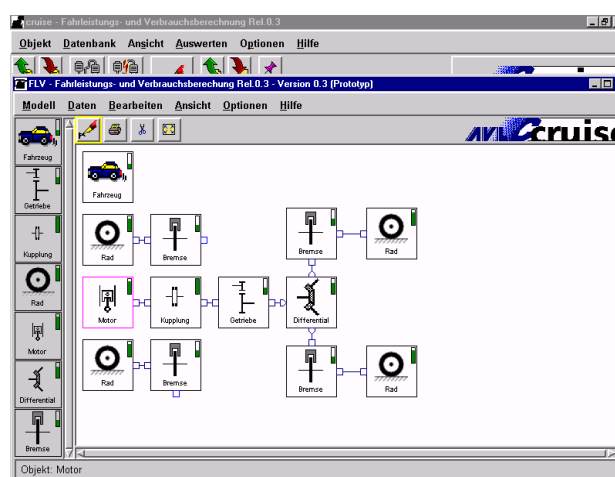


Fig. 1 Offline Vehicle Simulation

The results of the offline simulation are stored in a database and are fully compatible with the results of the testbed automation system.

A modern graphical user interface is provided to edit the vehicle model and is shown in figure 1. The user can select between a wide range of model elements and also incorporate his specific coding.

## 3. Standard Online Simulation

In the next development phase not all components of the future vehicle are available as prototypes on the testbed and have to be simulated in order to ensure a normal operation of the unit-under-test. For example an ECU might need data from the transmission, which is simulated on the engine testbed.

On modern testbeds the following standard simulation models are already available:

- Vehicle (Roadload, Mass, Brakes, Drivetrain)
- Manual Transmission (MTR)
- Automatic Transmission (ATR)
- Combustion Engine
- Driver (Throttle, Brake, Gearshift)

Those models have a predefined structure and the user can only change the parameterization of the model. But more and more user want to adapt the standard models to their specific needs by changing the model structure.

#### 4. Advanced Online Simulation

Modern online simulation software has to provide the user the capability to modify the following simulation models in the testbed controller software:

- Engine Control Unit (ECU)
- Transmission Control Unit (TCU)
- Continuously Variable Transmission (CVT)
- Shifting Strategy for Manual and Automatic Transmissions
- Brake Strategy
- Retarder and Auxiliaries Simulation
- Wheel Slip Simulation

Upon delivery of a fully functional standard model the user can start immediately after installation of the software with the operation on the testbed and incorporate his specific model features into the standard model step by step.

What is now missing are tools to develop the desired control algorithms and strategies for ECU, TCU and Traction Control and to create interfaces to the testbed, which should be easily adaptable to the user specific needs. Those tools have to be fully integrated into the testbed environment to ensure fast and easy operation.

#### 5. Testbed Integration

Now AVL can offer the necessary tools with the Advanced Simulation and the EMCON-LAB for the PUMA automation system and the EMCON Series 300 testbed controller. The needed components of the testbed can be graphically configured and SIMULINK models are generated automatically, in which the control algorithms and strategies are now

being developed or the standard simulation model adapted to the user specific needs.

Fig. 2 shows the graphical user interface to connect the different components of the testbed using a graphical representation of the functional elements.

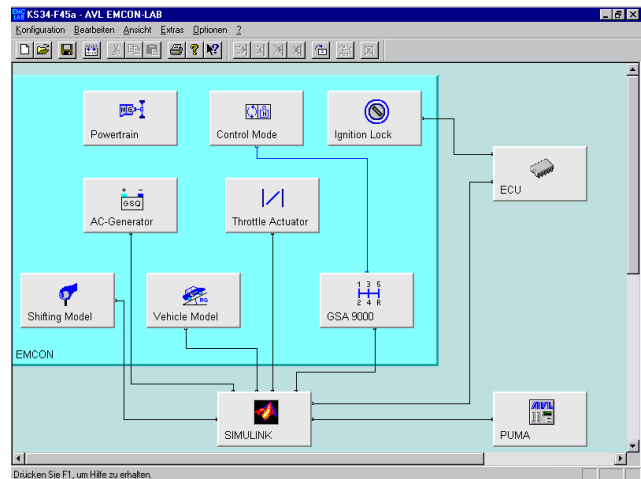


Fig. 2 Graphical Parameterization

For example the desired accelerator value of the driver simulation is redirected to the SIMULINK model and it is decided there, how to manage this request for acceleration depending on the actual driving situation. From the SIMULINK model the actual throttle actuator is controlled and the ECU / TCU can be influenced via ASAP 3 or CAN bus interface.

In order to judge the actual driving situation, the user can access any value from the vehicle simulation and track profile. The EMCON-LAB configures the SIMULINK model with access to the EMCON testbed controller, the PUMA automation system and the ECU interface.

The SIMULINK model is calculated in real-time on a Simulation-PC, which is connected via a high-speed datalink to the testbed controller, as seen in figure 3. This approach combines the flexibility of the open PC simulation environment with the safety and real-time capability of the testbed controller.

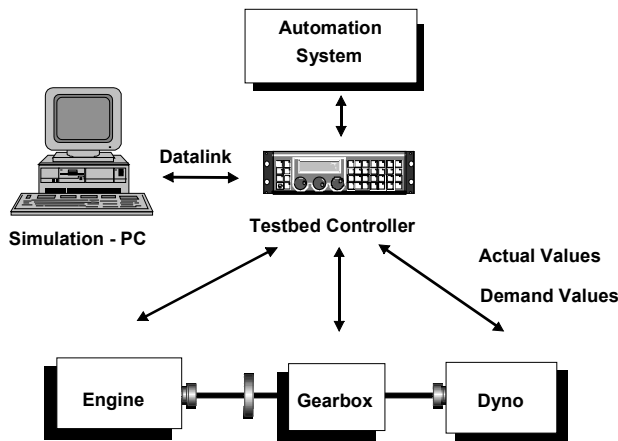


Fig. 3 Testbed Configuration

After rapid-prototyping with the SIMULINK model the control algorithm is implemented in the actual used ECU hardware.

In the next development step the ECU hardware is interfaced with the transmission simulation on the testbed using the open simulation model. For this application the actually used SIMULINK automatic transmission model is shown in figure 4.

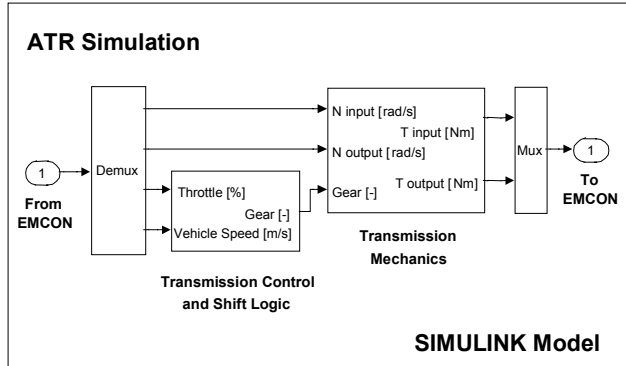


Fig. 4 Online Transmission Simulation

## 6. Summary

The modern development process needs flexible and integrated software tools during the offline design phase and prototype phase on the testbed to achieve the fast development times which are required today.

AVL can offer the customer with the offline simulation CRUISE, the testbed controller EMCON Series 300 together with the testbed automation

system PUMA a fully integrated product line to meet those goals.

The following list contains customer applications which currently use the advanced simulation together with EMCON Series 300 testbeds to incorporate their specific needs into the simulation models:

- Engine Control
- Combustion Engine Simulation
- Brake Strategy
- Auxiliaries and Retarder Simulation
- Driver Simulation with Lookahead Capability
- Hybrid Engine Control
- Alternative Propulsion Control

## References

- (1) Kriegler, W. and Mayrhofer, J.: AVL Universal Hybrid System, Components and Developing Tools, 4<sup>th</sup> International ATA Conference, Florence Italy, March 1994.
- (2) Kriegler, W., Albrecht, K. and Mayrhofer, J.: Hybrid Drive Trains - a Comparative Study, 27<sup>th</sup> ISATA Conference on Electric, Hybrid and Alternative Fuel Vehicles, Aachen Germany, October 1994.
- (3) Kriegler, W., Albrecht, K. and Mayrhofer, J.: A Hybrid Drive Based on a Structure Variable Arrangement, 12<sup>th</sup> International Electric Vehicle Symposium EVS-12, Anaheim USA, December 1994.
- (4) Putz, G. and Zrim, A.: Universal Hybrid System - Results of Steady State Tests and Simulations, AVL-Report TV621/16, Graz Austria, 1996.
- (5) Putz, G. and Zrim, A.: Universal Hybrid System - Results of Dynamic Tests and Simulations, AVL-Report BS 0001, Graz Austria, 1997.
- (6) Schyr C., Putz, G. and Zrim, A.: Flexible Simulation on the Testbed, 8<sup>th</sup> International VDI Congress, Böblingen Germany, April 1997.

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