Electronic Stability Program (ESP) for Trucks on the Daimler Driving Simulator

ESP FOR COMMERCIAL VEHICLES

The Electronic Stability Program (ESP) safety system is a common feature in passenger cars nowadays and has proven to be an essential component in the reduction of traffic accidents. Electronic "stability control" and "rollover control" have been available since 2001 for commercial vehicles. The system used for trucks and buses has two basic functionalities:

The "stability control" functionality works similar to passenger car ESP systems. Sensors measure the steering wheel angle, the yaw velocity and the lateral acceleration of the vehicle and feed the values into a simple vehicle model. As soon as this model detects a big difference between the desired and measured vehicle path, either in an oversteering or an understeering direction, individual wheels are braked to generate a moment around the vehicle's vertical axis, which stabilizes the vehicle movement (Fig. 2). For commercial vehicles, especially when loaded, these limits of adhesion are usually only reached on roads with a low coefficient of friction. For trucks and buses travelling on dry road surfaces, it is more important to prevent them from reaching the rollover limit (Fig. 3).

The "rollover control" functionality limits the lateral acceleration of the vehicle to a pre-defined value which is dependent on the vehicle mass. When the vehicle reaches this maximum value, all the wheels of the towing vehicle and the trailer are braked to reduce speed.

For Daimler trucks, the system is integrated into the electronic braking system and is sold as “Telligent Stability System” in a safety package together with other systems like lane keeping assistant and active cruise control. However, until now the system was only

Fig. 2: ESP stability control

Fig. 3: Truck rollover
available for tractor/semitrailer combinations, and the percentage of vehicles equipped with the system is still low. This is why the legislative committee of the European community has decided to make ESP systems mandatory for trucks and buses. The newly defined legislation ECE-R13 will go into effect this year starting with mandatory ESP systems for coaches and for tractor/semitrailer combinations, where the system is already available. All other trucks and buses (apart from vehicles used for construction purposes), will have to follow by 2014.

This makes it necessary for truck and bus manufacturers and braking system suppliers to develop the system for a wide variety of commercial vehicles. As the number of vehicles which can be used for proving the system functionalities in field testing is limited by material expense and time, it is necessary to use vehicle dynamics simulation to support the development of the system. A myriad of commercial vehicle parameters, such as different axle configurations, different wheelbases, tire variations, varied loading conditions, etc. can be incorporated into the simulation.
ESP SOFTWARE-IN-THE-LOOP CODES FOR SIMPACK VEHICLE MODELS

To study vehicle behavior with ESP in simulation, a code of the system has to be integrated into the vehicle dynamics simulation tool. The CAE analysis division of Daimler Trucks uses SIMPACK as a standard multi-body simulation tool for different purposes. SIMPACK offers various possibilities for the integration of system codes into the simulation, e.g. the MatSIM interface for the integration of Simulink® codes.

The SIMPACK model consists of detailed component based models of axles and cab mounting. A detailed model was also used for the steering system. The frame includes torsional bending behavior.

For the integration of truck ESP into SIMPACK, Daimler and the system supplier WABCO have chosen MATLAB® and Simulink as an exchange and integration platform. The Daimler CAE analysis division uses the SIMPACK code export feature to generate a Simulink S-Function, which is combined with an S-Function of the ESP code, delivered by WABCO. The driving maneuvers and the evaluation of the results are generated within MATLAB and Simulink.

TRANSFER OF SIMPACK MODELS TO THE DAIMLER DRIVING SIMULATOR

The Daimler driving simulator in Berlin has been in existence since 1995 and will be moved to Sindelfingen in 2010. A complete car or a truck cabin is installed on a hexapod which can additionally be moved in the horizontal direction. The movements of the simulator are generated by a vehicle simulation model. This simulator serves for investigations of the interactions between the driver and the vehicle. On one hand, it is used for subjective evaluations of driver assistance systems. For example, the “brake assist” that guarantees full braking application during emergency situations was developed based on simulator investigations. On the other hand, the simulator is also used for the subjective evaluation of parameter changes within the chassis layout during the development phase of new vehicles.

The Daimler Trucks CAE analysis division has used the driving simulator since 2006, when the real-time capabilities of SIMPACK

Fig. 6: SIMPACK vehicle model

Fig. 7: Simulink simulation with exported SIMPACK model and ESP code

Fig. 8: Daimler driving simulator
allowed the transfer of simulation models used for the chassis layout directly to the driving simulator (see SIMPACK News 2/08). Since then, several simulated driving tests have been conducted with SIMPACK models. The results were used to define target values for the vehicle dynamics of new truck or van generations and for the subjective evaluation of many chassis variants before field testing.

ESP INVESTIGATIONS ON THE DRIVING SIMULATOR
A first test with ESP for trucks on the driving simulator was conducted in November 2009. The test served as a basis for investigating if the simulator could give additional value to the simulation-supported development of ESP for trucks. The basic questions were if the simulator would be able to realistically reproduce the interventions of an ESP system for trucks, and if the simulator could be used for optimizing the system, e.g. for defining the intervention threshold values for different vehicles and various vehicle parameters. As the Windows-based MATLAB and Simulink Software-in-the-Loop (SIL) environment was not suited for the UNIX operating system of the driving simulator, a decision was made to use a different approach for this first test. A Fortran code, which simulates the basic ESP functionalities of stability control and rollover protection, was integrated by SIMPACK into a real-time vehicle model as a user routine. The model was then exported into the simulator environment together with the user routine, which then could be parameterized after the code export via the SIMPACK “subvar” file. This has the advantage of a flexible parameterization during the simulator tests. In addition to the parameters of the ESP system, vehicle parameters were also varied during the simulator test, i.e. loading conditions, steering parameters and tire characteristics. To evaluate the ESP interventions on the driving simulator, different driving situations were chosen, all based on straight-ahead driving on a highway track. Pylons were used for various lane-change and slalom maneuvers. With the aid of different sets of MF-Tyre tire parameters either a dry road surface or a low friction road could be simulated.

As a main result, it was proven that the interventions of the ESP system on the driving simulator produced a realistic feel of the system. In addition, the influence of varied vehicle parameters and loading conditions on the interventions of the systems were shown to be realistic. Yet, for a complete evaluation of the ESP system on the simulator, the simple code used for the first test is not sufficient. For this, it will be necessary to integrate the complete system functionality, i.e. the interaction of the ESP system with the vehicle drivetrain.

RESULTS AND FUTURE WORK
During a first test of a truck ESP system on the Daimler driving simulator, it could be shown that the combination of SIMPACK vehicle models with a Software-in-the-Loop code of the ESP system is able to realistically reproduce the stability interventions of the system and thus can be used for optimizations of the system for a wide variety of vehicles and vehicle conditions. In the next step, a complete WABCO code of the truck ESP will be compiled on a Linux system and integrated into SIMPACK as a user routine to obtain the complete functionality of the system on the driving simulator.

“...the combination of SIMPACK vehicle models with a Software-in-the-Loop code of the ESP system is able to realistically reproduce the stability interventions of the system...”

Fig. 9: Transfer of SIMPACK models to the driving simulator

Fig. 10: Lane change and slalom maneuver on the driving simulator