Modeling driving cycles with microscopic traffic flow simulation-in-the-loop

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The certification of fuel consumption of a specific vehicle is carried out on standardized driving cycles and under standardized ambient conditions. In order to overcome the restrictions of driving-cycle-based testing, a new approach is investigated at Karlsruhe Institute of Technology (KIT). This approach combines a microscopic traffic flow simulation model of a dense urban area and real automotive hardware components in a so-called X-in-the-Loop framework.

In Europe the New European Driving Cycle (NEDC) is obligatory for fuel consumption certification. The NEDC represents a generic driving maneuver giving the vehicle speed over time as well as the gear in case of manual transmission drivetrains. Although a standardized driving cycle oriented methodology is able to compare different vehicle types with regard to fuel consumption, this approach tends, in most cases, to deliver too optimistic fuel consumption. In real driving situations on the road the fuel consumption tends to be higher as given in the vehicle brochures.

The X-in-the-Loop framework, a technique for real time embedded systems testing, includes real test beds (physical simulation) as well as numerical simulation models. In the case of vehicle fuel consumption measurement the test bed can be a roller dynamometer for a complete vehicle including a real or a numerical driver. If only the drive-train of a vehicle is existent, the test bed configuration can include several prime movers for hybrid vehicle configurations and up to four output machines in all-wheel-drive configurations. In the last mentioned test bed configuration the vehicle driving resistance, which is a parameter of e.g. air drag coefficient or the vehicle mass, must be computed in real-time during the driving maneuver. It is conclusive that less existent real drive train components imply a higher numerical simulation effort for the complete vehicle. The X-in-the-Loop approach, developed at the Institute of Product Engineering, is a universal framework for system development, especially in this case the vehicle development.

The microscopic traffic flow simulation VISSIM, a commercial product by PTV group, is a tool for creating real-world conditions in terms of multimodal urban traffic flow. The core of the simulation is the car-following model based on a model developed by Rainer Wiedemann at the Karlsruhe University at 1974 and 1990. The realistic interaction of the simulated agents is provided by detailed setting of the lateral and longitudinal behavior in the traffic flow. The multimodal traffic flow stands for simulating private vehicles, public transport as well as slow modes represented by pedestrians and cyclists. The benefit of the micro simulation over the pre-defined driving cycle is the close-to-reality environment where vehicles are interacting with each other based on the car-following model. The simulation is capable of building a real-world network where the input is a heterogeneous traffic stream entering the network on a random base. This allows simulating real traffic conditions as experienced in the everyday traffic, and developing a number of what-if scenarios considering e.g. different driving behavior. In case of a simulated driver, the simulation can alter the acceleration distribution, the driver´s aggressiveness or even his attention to the current traffic. These cautious or aggressive driver profiles are suitable objects for the fuel consumption testing.

Another advantage of VISSIM is the stochastic characteristic of the simulation. The vehicle´s routing is not determined but only bounded by the simulated area. Thus the vehicle flows randomly in the traffic stream and leads to large extent of not pre-defined traffic situations. As a result, the speed, acceleration and gear number profiles are unknown all along the simulation period. These datasets present the initial base for data input into the X-in-the-Loop framework.

The combination of the traffic flow simulation and the X-in-the-Loop framework offers the possibility to accelerate the vehicle development, and, especially in terms of reduction of the fuel consumption, a more realistic driving situation in comparison to the NEDC or other drive cycles. For example new wet running clutch systems with reduced drag torque characteristics can be investigated in congested traffic situations with an idle running engine or new electric battery operation strategies can be evaluated for hybrid and electric battery driven vehicles.

The paper examines the challenges of real time X-in-the-Loop simulation to compute the average fuel consumption of a compact vehicle in simulated traffic flow conditions. The developed and successfully tested interface between VISSIM and the test bed framework enables to achieve more realistic average fuel consumption values compared to the state-of-the-art generic drive cycles. This approach includes a scalable driver model enabling implementation of all aspects influencing the vehicle´s fuel consumption. Together with multiplicity and randomness of the microscopic traffic flow simulation, the developed interface allows more realistic fuel consumption testing.