

Rating Mass-related Energy Demand for Vehicles with New Powertrain Concepts

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ABSTRACT

The combination of enhanced powertrains and adapted vehicle concepts can reduce the energy demand of vehicles significantly, especially when energy conversion efficiency rises and at the same time driving resistances decrease. In addition, new powertrain concepts are able to offer extra functionality due to a growing cross-linking with chassis and vehicle body. The design of highly linked vehicles and powertrain systems requires additional new development methods in order to answer interacting questions of driving dynamics and vehicle energy efficiency at an early stage of development.

In the paper a database-based simulation platform is presented which was developed at the IVK of the University of Stuttgart in cooperation with the Research Institute of Automotive Engineering and Vehicle Engines Stuttgart (FKFS). The simulation platform is used as an example to discuss mass reducing developments for various powertrain concepts.

INTRODUCTION

Almost every day technical newspapers present the latest innovations on the reduction of vehicles energy demand. The number of such suggestions is rapidly increasing. Enhancement of conventional powertrains and application of advanced powertrain concepts in particular can considerably contribute to the reduction of energy demand of vehicles while driving.

The effects of powertrain optimization usually depend on the target vehicle. This also applies to the reduction of energy demand due to alternative powertrains. It is not sufficient to analyze and compare the efficiency of powertrain

components in order to rate the whole concept. Instead it is absolutely necessary to consider interdependencies and effects on driving resistances while rating, too. Energy demand and emissions combined to the energy supply have to be taken into account as well. Extra functionality due to a growing cross-linking of powertrain and chassis as well as powertrain and vehicle body must be considered for a holistic approach.

New development methods and tools are needed for an integrated treatment of the various cross-linked questions on energy demand of vehicles while driving. These methods and tools have to go beyond simulating driving cycles. For this purpose a database-based simulation platform has been created at the IVK of the University of Stuttgart. It helps to holistically rate energy demand of vehicles while driving [1, 2]. In this paper the developed simulation platform will be used to evaluate and compare lightweight construction for two vehicles with different powertrain concepts.

NEW PLATFORM FOR RATING VEHICLE ENERGY DEMAND

The new database-based simulation platform for rating vehicle energy demand combines the mathematic and control abilities of MATLAB/Simulink and the advantages of the multi-body simulation tool SIMPACK (figure 1). The chosen simulation approach uses free in scale vehicle and vehicle component models. They can be parameterized automatically via a user interface from a vehicle parameter database and allow the holistic rating of vehicles with conventional and alternative powertrains. The platform proves its advantages especially in the discussion of the energetic relevance of driving dynamic parameters. It can be used for the closely linked optimization of driving dynamics and energy efficiency. Integration of additional accessories and electrical

consumer loads in available simulation models allows the testing of their energetic influence.

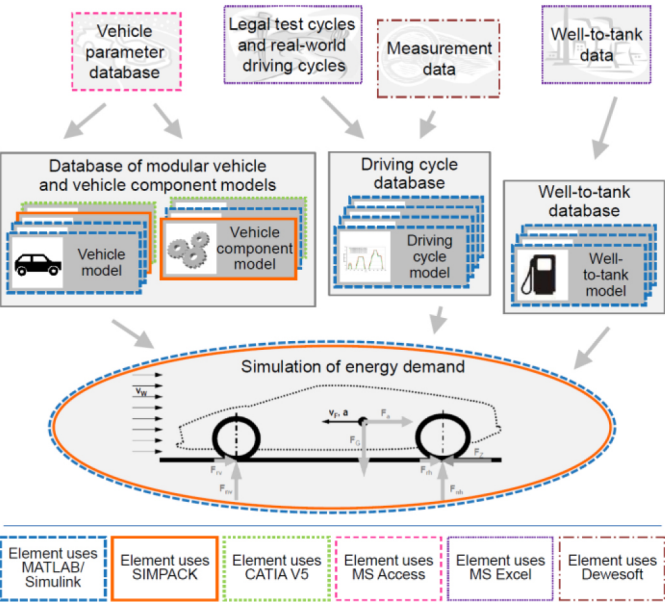


Figure 1. Concept of the platform for rating vehicle energy demand

Depending on the simulation target different vehicle and vehicle component models of adapted complexity can be used. They are based either on Simulink or on SIMPACK. A Co-Simulation of Simulink and SIMPACK models is possible, too. In order to analyze powertrain concepts approximately, a database of modular vehicle and vehicle component models was set up. Especially in an early stage of development the vehicle parameter database allows fast comparisons of different vehicles in order to identify energetic potentials. It can be used for the definition of development goals. The large driving cycle database contains legal test cycles, real-world driving cycles and measured driving cycles. The well-to-tank database supplies the necessary parameters for well-to-tank and well-to-wheel ratings.

DEFINITION OF REPRESENTATIVE VEHICLES FOR RATING VEHICLE ENERGY DEMAND

Reliable reference vehicles are necessary especially to study theoretical basics and to rate vehicle independent innovations and components developed by suppliers. To create such vehicles the vehicle parameter database of the simulation platform can be used. It contains more than 2000 vehicles. All parameters provided by the database have their origin in public available sources and give a wide overview of the market as well as the state of the art. The vehicle parameters in table 1 represent average and extreme values of specific

driving resistance relevant parameters for different vehicle segments. For the generation of these average parameters the sales figures of passenger cars in Germany in 2009 [3] have been considered. The single available values have been weighted according to the sales figures of the ten best sold vehicle models in Germany in each vehicle segment. The minimum and maximum values show the vehicle segment specific range. The parameters of all vehicles in a vehicle segment of the database are within this range.

Table 1. Driving resistance relevant parameters for various vehicle segments

		Small vehicle	Compact vehicle	Mid-size vehicle	Large vehicle	Luxury vehicle	Sport vehicle
Vehicle front area [m²]	Max	2,38	2,44	2,35	2,44	2,60	2,30
	Mean	2,10	2,19	2,21	2,27	2,32	2,02
	Min	1,92	1,94	2,08	2,12	2,15	1,60
Vehicle air drag coefficient [-]	Max	0,360	0,390	0,350	0,380	0,350	0,430
	Mean	0,321	0,314	0,295	0,289	0,289	0,335
	Min	0,290	0,280	0,260	0,250	0,260	0,270
Vehicle mass [kg]	Max	1570	1685	1892	2148	2735	2079
	Mean	1160	1369	1592	1761	2005	1534
	Min	966	1159	1358	1505	1605	945

The average parameters for the mid-size vehicle in table 1 are used in the following as a basis for the analysis of various lightweight construction effects. For this purpose two mid-size vehicles with different powertrain concepts are treated. Vehicle concept A uses an internal-combustion engine as single drive unit. The electrified vehicle concept B does not use an internal combustion engine. It has a tandem axle with two electric machines. This means that each wheel of the driving axle is driven by an electric machine via a constant spur gearwheel. Vehicle concept B is able to recuperate kinetic energy, vehicle concept A is not. The constant recuperation efficiency of vehicle concept B is 50 %. It was defined for the simulation in order to avoid the influence of engine characteristics on the simulation results. The parameters of both powertrains are summarized in table 2. The powertrains of both concepts were set up in such a way that the two vehicles have identical driving resistances. Due to the light electric machines and the non-existing multi-step transmission an electric energy storage of 155 kg could be installed in vehicle concept B. This allows a range of about 120 km driving the NEDC (New European Driving Cycle).