

A Method for Developing Specific Reference Cycles or Alternatively Test Cases for Commercial Vehicles and Their Auxiliary Systems

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ABSTRACT

In contrast to passenger cars, commercial vehicles exist in many layouts for different customer applications. The Daimler AG provides with their Mercedes Benz Trucks a product portfolio of 6 commercial vehicles (Econic, Atego, Axor, Actros, Zetros, Unimog), which are available in a multiplicity of model variants.

Therefore, the well-known driving cycles of passenger cars such as NEDC (Europe), the 10-15 mode (Japan), the FTP & FTP75 (USA) and others cannot be used in regard to fuel consumption or dimensioning of a commercial vehicle [1, 6, 15]. A diversification of type and usage of the commercial vehicles is obligatory necessary, as already shown in publications of Holloh et al. [10]

However, this paper offers a method which uses collected data from customers, in order to develop objective reference cycles or test cases. This described method can be equally used for both, creating the reference cycles of commercial vehicles mentioned above, as well as passenger cars. Especially when moving on to the more complex operating strategies and operating points or vehicles with many different auxiliary systems, this method is an even better assistant to create possible impartial test cases. With the help of these test cases, systems can be analyzed in respect to their behaviour regarding different quantities, like emissions of the combustion engine, power consumption of different auxiliary systems and others. The most important aspect of this method is that it is able to take the interdependency of different auxiliary systems to each other as well as to the whole vehicle into account by classifying operating points with an arbitrary wide range of different operating conditions and their respective frequencies.

In contrast to the World Heavy Duty Cycle (WHDC) this method does not only analyze the engine [14] but also the whole vehicle. The reference cycles or test cases developed this way can be used for (simple) testing or determination of new (sub-) systems, which are comprehensible and representative for different particular customer applications. However, this method does not take misuse maneuvers, which may damage the (sub-) systems, into account but only the most likely operating points during customer operation.

This paper describes the developed method using the example of a light duty vehicle as used in distribution of goods and its possibilities for generating an impartial representative reference cycle.

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1. INTRODUCTION

The further development of commercial vehicles evokes changes in multiple boundary conditions which affect each other in dependency of the allowed degrees of freedom set by the developer. Taking the possibility of using high voltage into account, existing functions can be realized by other functional principles. One example of this case is the vehicle deceleration, which is supported by an electric motor. In this scenario the service brake is unloaded to a certain degree. This affects the demand for compressed air and thus the air

compressor unit and its further periphery. This simple example shows the need for a holistic view of the vehicle, the driver behavior and the environment, which shall be described, developed and validated by using the so called X-in-the-loop-framework (XiL) in this paper. Especially the great field of application of commercial vehicles must be considered much more than in passenger cars. Well-known test cycles like the NEDC (Europe), the 10-15 Mode (Japan), the FTP72&FTP75 (USA) do exist. The derivations of these cycles are not developed in a way that allows a methodical adaption for commercial vehicles. For example the last two

cycles are based on measured data from driving cycle experiments and have not been analytically developed. [1, 6, 15]. However, in the future new test methods, which are more impartial, will be demanded, especially regarding hybrid vehicles. Until now, no test case has proven to be adequate [4,8].

In product development the according modeling of principle and design [3] of auxiliary systems must be examined in consideration of the specific customer usage. The field of application can change when choosing a specific vehicle. The Daimler AG offers with its brand Mercedes-Benz Trucks a range of products of 6 vehicles (Econic, Atego, Axor, Actros, Zetros and Unimog), which are available in a multiplicity of types.



Figure 1. Products of Mercedes Benz Trucks: Econic, Axor, Actros, Atego, Unimog

In order to deal with the multiple customer applications and vehicle diversity a methodical tool is required, which creates reference cycles of the specific applications in a most objective way and also takes the customer into account as early as possible. In this paper a possible approach is shown, using the example of the Atego as a vehicle for the distribution of goods. An important goal for the further development of commercial vehicles is the reduction of power consumption of the auxiliary systems. This goal can only be achieved in combination with new operation strategies and functional principles. The impartially derived reference cycles are created in order to determine the average necessary power for different scenarios and topologies of commercial vehicles.

2. STATE OF ART

2.1. Terms and Definitions

Validation is the process of rating a system or individual components with the aim to declare whether the right product has been developed. The evaluation is done with help of subjective criteria regarding the use case or customer expectations. The verification can be a part of the validation. The validation itself is performed when the customer is also taken into account, see [figure 2](#) (validate = verify + survey). Validation is the central activity in the product development cycle. [2]

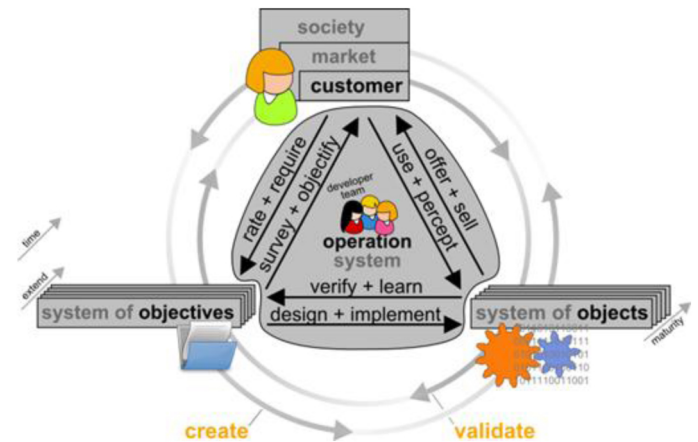


Figure 2. Definition of validation in the product development (IPEK) [2]

X-in-the-Loop is a framework which 'takes the complete system as well as the environment and the driver into account, even if the unit under test is only a single component of the whole mobility system. Given that the system is already a complete vehicle, it can be validated by an arbitrary driver in any environment' [2]. [Figure 3](#) shows a 3 dimensional view of the interacting system models in the XiL approach, showing the unit under test and the remaining subsystem in different degrees of fidelity, maturity and partitioning.

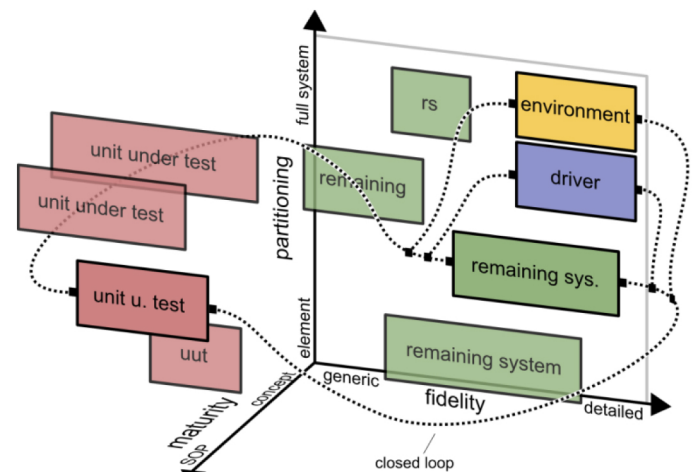


Figure 3. The XiL framework [2]

The purpose of [figure 3](#) is to visualize the solution space of modeling. The challenge lies in finding the 'right' model, which delivers the required data and keeps the effort limited at the same time. Therefore it is important to decide which level of maturity is needed for the unit under test need. The maturity is characterized by the stage of development, i.e. prototype or series components. Furthermore it can be selected whether the unit under test has all features of the final product or only some. The same applies for the necessary remaining system. The fidelity characterizes the

necessary accuracy of the remaining systems which is needed for the data acquisition in interaction with the investigated unit under test. The last question is the definition of the system boundaries. This is represented by the partitioning and can only be answered with system knowledge. One example is given by an electric air compressor unit: The unit under test can consist of only the physical compressor piston setup on the test bench. In this case the electric motor is part of the remaining system and is simulated by the test bench motor or the dedicated motor could already be included in the unit under test. It is important to keep in mind that all components mentioned can be real physical models or simulated ones. Choosing the 'right' implementation is task of the developer and is strongly related to the upcoming questions in the development process.

2.2. Approaches to Identify Power Consumption

One helpful approach is to use measured data from real driving maneuvers to identify the frequency of operating points of auxiliary systems. Therefore, cycles are driven by the manufacturer of commercial vehicles which are supposed to be representative for specific customers. The data acquired this way is supposed to be strongly related to actual customer usage and these measurements are the basis for further investigations.

In order to identify the power consumption of the engine an approach developed by the World Heavy Duty Cycle Project (WHDC) exists, which uses the engine with only the necessary auxiliary systems on a test bench to measure the power consumption. [14] Using a very large data base of collected information and driver behavior around the world, statistical information about different regions worldwide shall be condensed. This is done with help of a velocity time profile which also shows a scaled engine power curve in order to illustrate stages of towing and pulling, see figure 4. By combining this profile with generic vehicle models a translation into engine cycles, which use scaled engine speed and power demands, is achieved. This cycle is supposed to be applicable to all engine sizes. Also different aspects of the regions (Europe, Japan, USA) and roadways are weighted (urban, rural, motorway).

In a further approach to identify the consumption of engines, the demanded loads of the different customer classes are being surveyed. Holloh et al. suggests a classification into seven 'Usage-Profile-Cluster'. [10] Thereby different torques at specific engine speeds are demanded in a specific frequency. The target is to capture different vehicle types as simple as possible and defining their specific fuel consumptions.

Another stochastic approach which concentrates operating points of an arbitrary amount of different vehicle component states at same time is shown by Oberfell et. al. [12, 13] Here, the operating points of the examined auxiliary systems are being condensed in the context of the whole vehicle by using

a multidimensional histogram. In dependency of the frequency distribution, an operation strategy is developed which is described time independently. Based on the frequency distribution, it is already possible to classify customers. Oberfell et al. therefore distinguishes the previous simulations approaches into 'longitudinal dynamics simulation' and 'statistical longitudinal dynamics simulation'. He introduces his approach as a so called 'stochastic state analysis', which has a distribution function as input and contains a remaining vehicle model and a stochastic solving process. The results demonstrate the advantages of this development methodology in aspects of developing an operation strategy.

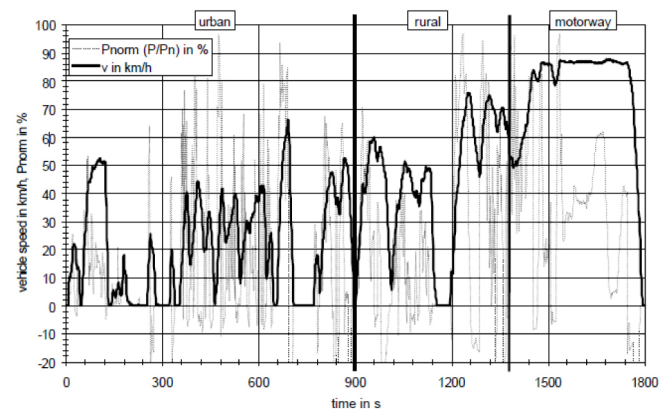


Figure 4. The world wide transient vehicle cycle (wtvc) [14]

3. A NEW METHOD FOR GENERATING IMPARTIAL REFERENCE CYCLES FOR VEHICLES

3.1. Objectives and Method Overview

Due to the hybridization of light and heavy duty vehicles further potentials can be tapped by a holistic examination of the vehicle system. Therefore, different auxiliary systems and their consumers as well as the power train topology must be changed at the same time in some cases. In order to choose the right alternative auxiliary systems and topologies, a profound knowledge of the interaction and operating sequence of these auxiliary systems is necessary. In order to determine the average time dependent power consumption, customer specific maneuvers are essential. The objective has to be the advancement of the known approaches, so that the different customer usage profiles and power consumption of the auxiliary systems can be predicted according to their interaction with one another with the help of adequate models of the remaining vehicle (cf. XiL). Such an approach is introduced with this new method for generating impartial reference cycles for vehicles.