DEVELOPMENTAL METHODOLOGY FOR GENERIC COMPILATION OF LOAD CASES FOR CONCEPTUAL DESIGN OF COMMERCIAL VEHICLES

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ABSTRACT

The goal of this methodology is to achieve a tool, which generates generic load cases for commercial vehicles. These are required for the future conceptual design of energy and thermal management. Fuel and Gas are continuously getting more expensive for years. To save fuel and costs the vehicles should be optimized.

Commercial vehicles are used for many different application purposes. The load cases are just as well varying for different purposes. For example, it is not possible to compare the load conditions between a long distance transport vehicle with a garbage collection truck. The first of them is used in a stationary, the second one in a stop and go purpose. Specific load cases have to indicate those differences and build up a basis for the future design of the thermal and energy management of power train and auxiliary aggregates.

First of all one must collect the real load cases, e.g. via GPS, and prepare them by an innovative method. The load cases are analyzed by their different uses. The working and driving load profile have to distinguish. The Engine can be used in a different way. Some of the drive auxiliaries are turning-off and those for stationary work are turning-on. During the second step the particular load case would be evaluated by its statistical frequency distribution. In the next step the chronological sequence of individual load cases would be considered. It will be analyzed for the length of acceleration or braking sequences. Afterwards the base, average and peak load are analyzed, to show the utilization of this vehicle. The load cases will be completed. Several load components are generated off a statistical evaluation under consideration of the weighting of the load cases. The prepared areas from the above mentioned steps also included in the load components results. In turn these components are used to compose the specific reference load profile. That is the basic of the simulations surroundings.

INTRODUCTION

To improve the efficiency of commercial vehicles and to develop new vehicle concepts the information of the vehicle route is indispensable. Specific load profiles are intend to illustrate these differences and to form a basis for future thermal and energy management design of power systems as well as the vehicles work equipment. For this purpose, real-life velocity and load profiles are recorded. For this purpose an innovative methodology is developed within this research: Routes are stored in a database and categorized. Furthermore, the appropriate energy and thermal management are designed. If necessary, a separate operating strategy is created. Finally, the method generates a simulation model which includes the previously created load case, the individual operating strategy and the selected parameters for the cycle times and characteristic of the engine and auxiliaries.

The use of commercial vehicles is increasing steadily; by 2030 alone the number of long-haul vehicles is expected to have doubled over long distances traffic (Daimler 2009). Commercial vehicles have a versatile range of applications. The trucks on the highway are the most known commercial vehicle variants, i.e. the trucks for urban traffic or for construction. "Commercial vehicle" refers to a variety of other applications as well, though, e.g. the tractors in the agricultural sector and the excavator in construction. The size of each vehicle varies from simple garden excavator over the mining vehicles to the special coal mining excavators. Even special utility vehicles such as Curiosity which currently is to be found on our neighbor planet the Mars, is considered to be a commercial vehicle.

If all these use cases compared with the manageable field of cars, the question will be: How vehicles have to be tested, a generalization makes little sense. The consumption of cars is currently investigated in the New European Driving Cycle (NEDC). There are also some similar emissions test cycles in the commercial vehicle sector. This allows the EURO classification. For commercial vehicles the acquisition and maintenance costs are playing an important role. Cars are more a status symbol in which costs are the second rate considered over design and image.

Optimizing the design of commercial vehicles on the actual application allows a reducing of operating costs and protecting the environment in the long term. For example the load profile of a long-distance transport vehicle with a waste collection vehicle is not comparable. The constant load and speed range compared to the constant stop-and-go traffic is very important for the design characteristics of the vehicle.

COMPLEX OF PROBLEMS WITH CURRENT USED DRIVING CYCLES

Currently a lot of different driving cycles are used. In the following chapter a short overview about driving cycles and adapted cycles is given. Parts of the upper explained mythology used in real load case and the NEDC are shown.

Overview currently used driving cycles in Europe

The most used and public driving cycle is the New European Driving Cycle (NEDC). That cycle is used for all passenger cars excluding light commercial vehicles. It is still a synthetically generated cycle and it is used in Europe. This cycle didn't cover the real drive scenario. There are no elevations included and the main parts of the cycle are acceleration, braking and strictly continuous driving.

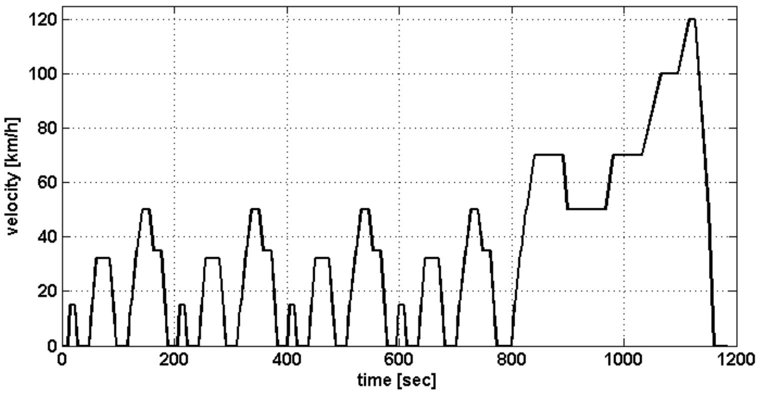

Figure 1: New European Driving Cycle (NEDC)

A driving cycle that is more authentic with a real driving has to be generated. In the European project ARTEMIS (Assessment and Reliability of Transport Emission Models and Inventory Systems) the correspondent Common Artemis Driving Cycle (CADC) was developed, based on statistical analysis of a large database of European real driving cases. The cycles include three driving cycles: Urban, Rural and Motorway. For the current development with these cycles give a better real behavior than NEDC.

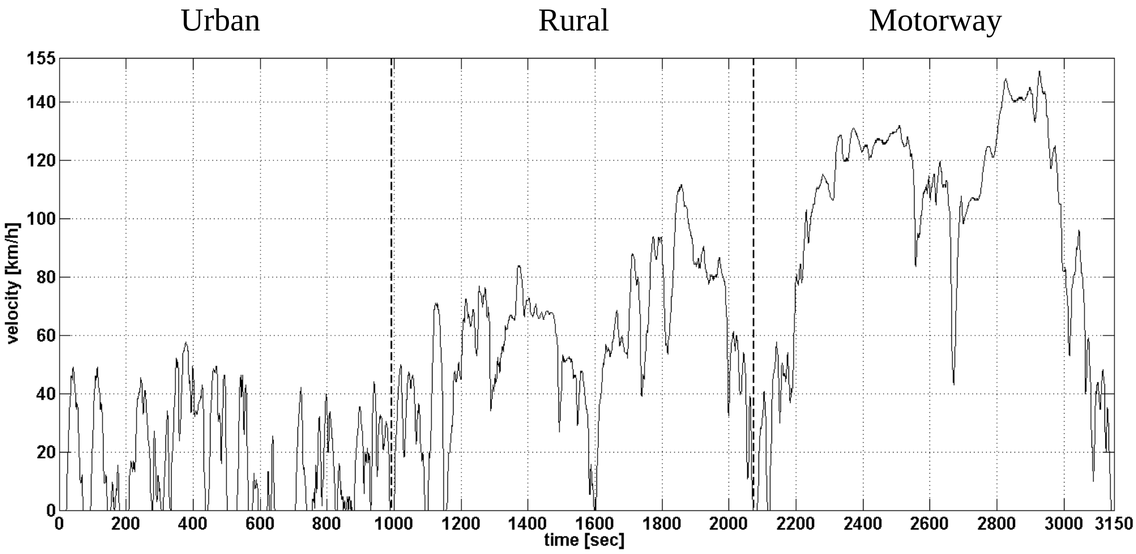

Figure 2: Common Artemis Driving Cycle

If we take a look abroad to compare, they are using different diving cycles. Japan applies the ‘10-15’ this is also a synthetic cycle that looks close to the NEDC. But Japan has different speed limitations, so the cycle has a different velocity distribution.

In the US they use the ‘FTP-75’. That cycle is not a synthetically one, it’s a real drive cycle. It includes also a hot and cold start phase. The different speed limitation of that country and the imperial system give their own characteristics.

Heavy duty vehicles are using different cycles. The stationary cycle ESC (European Stationary Cycle) has been introduced together with the transient cycle ETC (European Transient Cycle) for emission certification of heavy-duty diesel engines in Europe starting in the year 2000. Smoke opacity is measured on the ELR (European Load Response) test. (Kurek, R. (2006))

In Figure 3 and Figure 4 the ETC is pictured. In the upper figure, the speed over the time is shown. It is separated into the categories ‘urban’, ‘rural’ and ‘motorway’, like in ARTEMIS for cars. Figure 4 reflects the percent scaled torque shown over time.

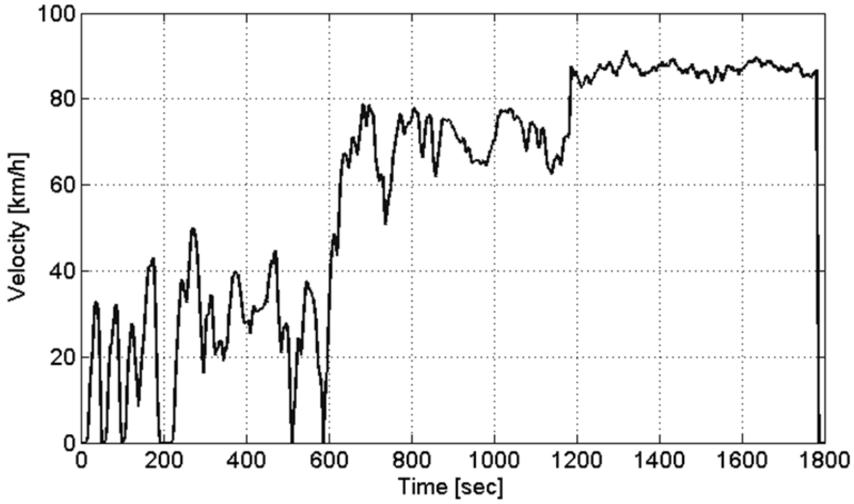

Figure 3: European Transient Cycle (ETC) speed over time

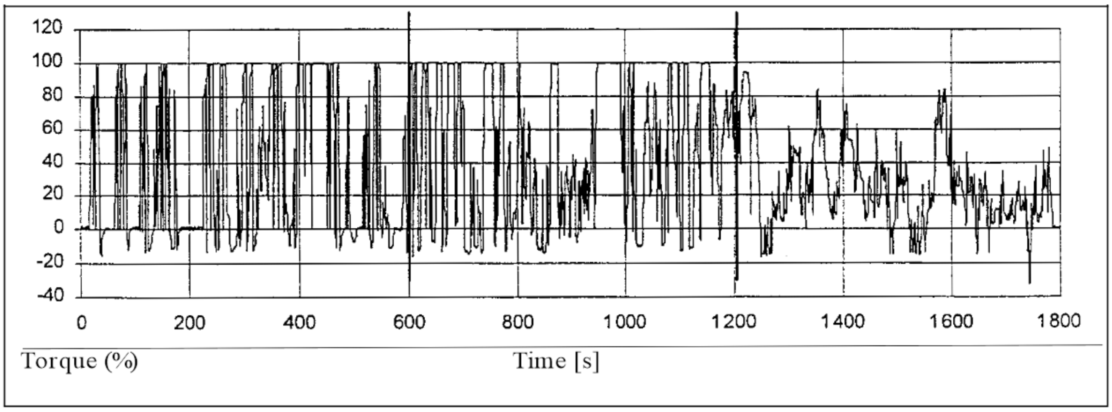

Figure 4: European Transient Cycle (ETC) torque over time, EU (1999)

The *Figure 5* shows the European Stationary Cycle with the stationary points of percentage load over the percentage engine speed.

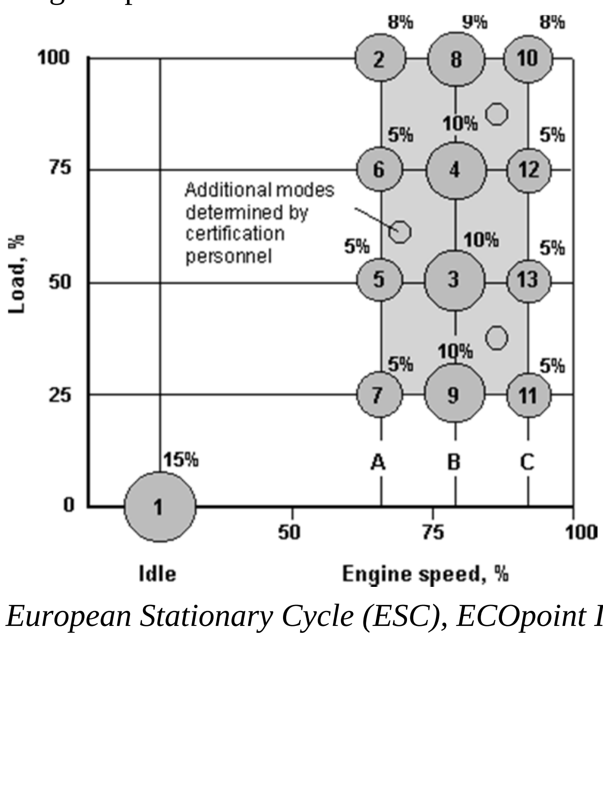

Figure 5: European Stationary Cycle (ESC), ECOpoint Inc (2013)

Driving cycles in studies

Daimler Trucks North America uses different self-created cycles for testing their trucks in advanced engineering. As example for the typical highway route, they use a cycle on the I5 from Portland to Canyonville and back. For the city they drive a city cycle in Portland. Based on those cycles Daimler develops the energy management of their heavy duty vehicles.

One famous driving cycle used for the heavy duty trucks in Germany is the autobahn route from Stuttgart to Hamburg and back. The route passes along the A7 and the 'Kasseler Berge' that is an area with high slops. But this route is for long-distance transport vehicles only and therefore it is not suitable as a cycle for rural or urban delivery vehicles.

In a study on the improvement of the efficiency of commercial vehicle transmissions for a sustainable road transport from the Austrian Federal Ministry for Transport, Innovation and Technology in cooperation with the TU Wien (ESEA), Joanneum Research and AVL List they are adapting public driving cycles. In the study the ARTEMIS cycles for urban, road and motorway were applied. These cycles were adapted and scaled over the speed and they were merged for different application purposes. (Kloess, M (2011))

Example for the difference between a real-life driving cycle and the ETC

For this example we chose a tank truck that started in the south surrounding of Stuttgart next to Weil der Stadt and drove to the Rhein harbor in Karlsruhe. There the truck filled up the tank with fuel. The truck first drives over a rural road to the motorway. In Karlsruhe the truck exits the motorway and drives along the rural road to the harbor. In the tank load area the vehicle is moving at a slow speed, frequently interrupted by stops. After the filling the truck takes the same way back to the motorway. Back time the driver takes another exit and drove a different rural way back to starting point. The longest distance was the truck running on the motorway. The trip is shown on the maps on *Figure 6*.

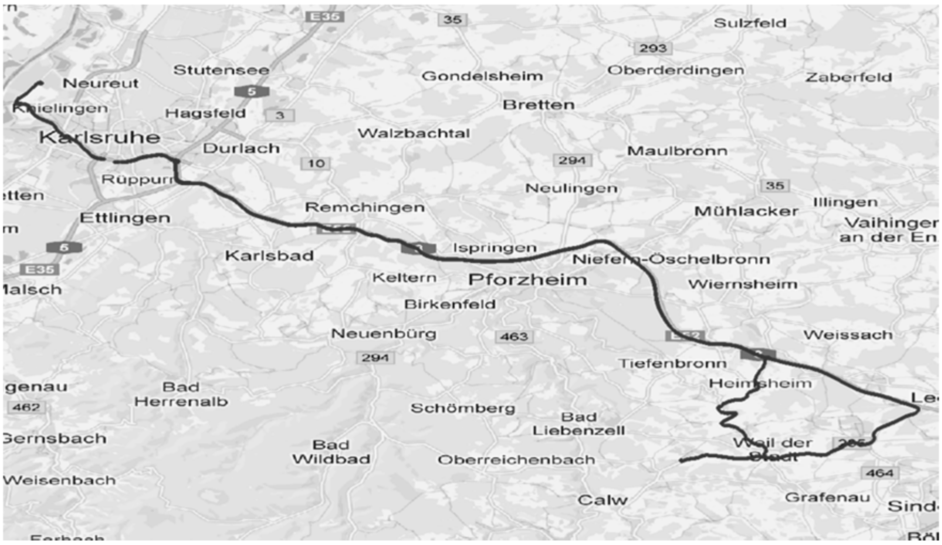

Figure 6: Example ride shown on a map

The speed of the vehicle is pictured over the entire trip. The part of the motorway can be identified easily due to its raised speed, as well the stop-and-go within the traffic jam. The tank filling is shown as the slow speed, cause of the GPS junk. In *Figure 7* (*Example ride speed over time*) it is reflected.

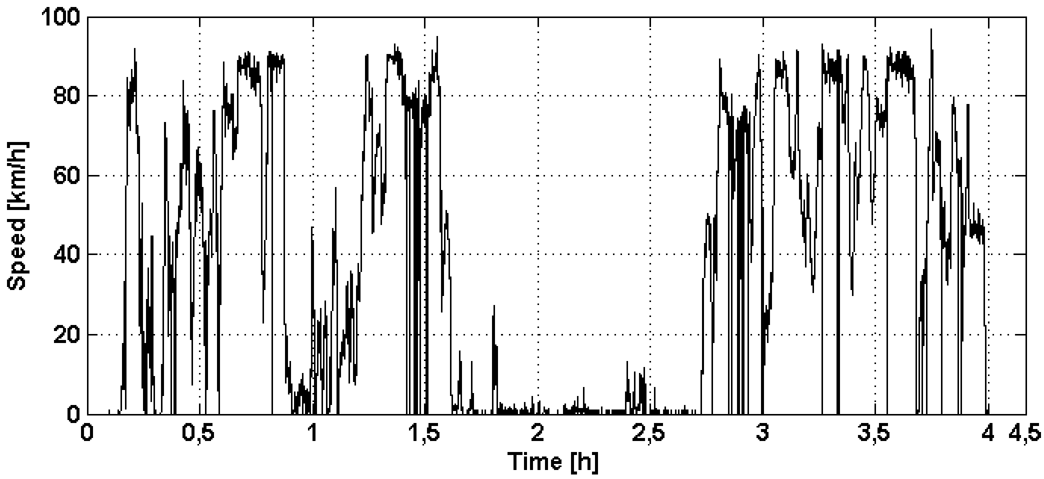

Figure 7: Example ride speed over time

The *Figure 8* shows the elevation of this tour. It is plotted over the time. The tour was driven along couple smaller valleys down to the harbor (100m). Backward the truck has to climb up.

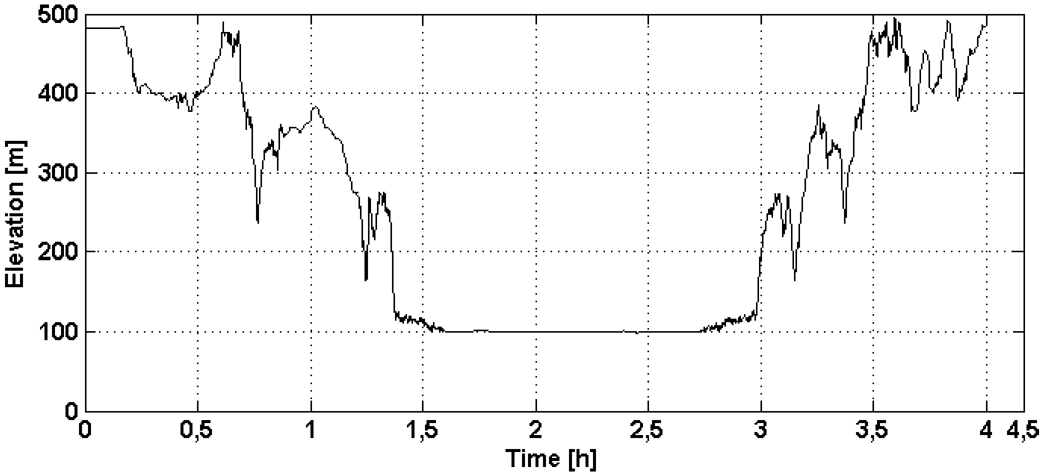

Figure 8: Example ride elevation over time

An analysis of the velocity in connection with the percentage distribution of the velocity is been shown on the following figure. The average velocity gives an approximation if the real drive and synthetic driving cycle close to each other. As shown on the figure the real drive has a higher distribution of high velocity, based on the long motorway drive. The velocity parts in higher velocities are more frequent. In the ETC this is a little bit different. The velocity distribution looks like three parts (Urban, Rural and Motorway). Each part has a special velocity average (30km/h, 70km/h and 90km/h). The high peak shows that the vehicle is running on the motorway with close the same velocity. This mean there are no bad traffic situations.

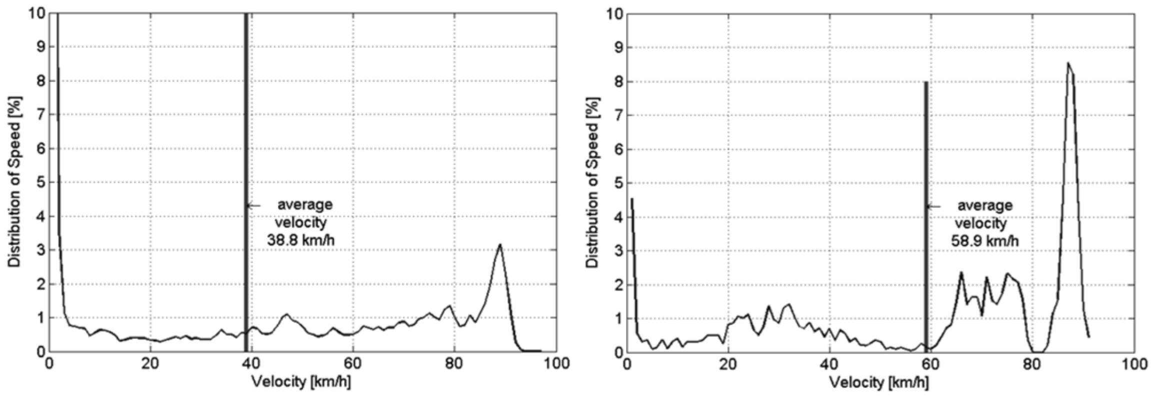

Figure 9: Distribution for the velocity of real drive and ETC

For the elevation we look also for the percentage distribution of slope. The ETC is a strictly flat cycle so there is a constant elevation of the track. This means that the slop over the whole cycle is zero. But the real world is not flat at all. Most parts of the world are rough and have hills and mountains. So including the elevation of a track changes the purpose generally. The following picture shows the distribution of the slope for the real drive. We see that the slope is like a Gaussian distribution with a peak in the middle.

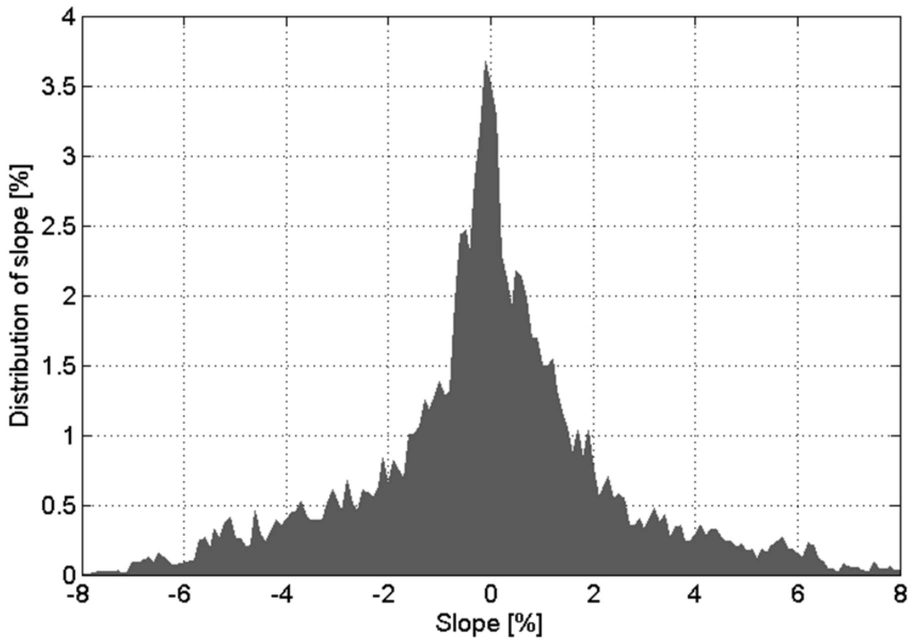

Figure 10: Distribution for the slope of real drive

If we take a focus on the start-stop-parts for the different cycles we see that in a jam-free highway route (*Figure 12* on the right parts) the stops are close to zero. That is the same for the ETC. Only the velocity is different. The velocity of the ETC is like a constant drive with small deviation. In the real drive the velocity has higher deviations. For the rural parts the ETC has no stops, but in the real drive there are some. That can be traffic lights, roundabouts or intersections. The test truck didn't drove in the city, so there is no data to compare the urban part. If we analyze the start-stop-parts over the time, we can see that the ETC has no stops in rural and motorway. The ETC is a good average of all driving situation. But the most trucks are more specialized. So the focus of the individual cycle will be important. (*Figure 11* and *Figure 12*)

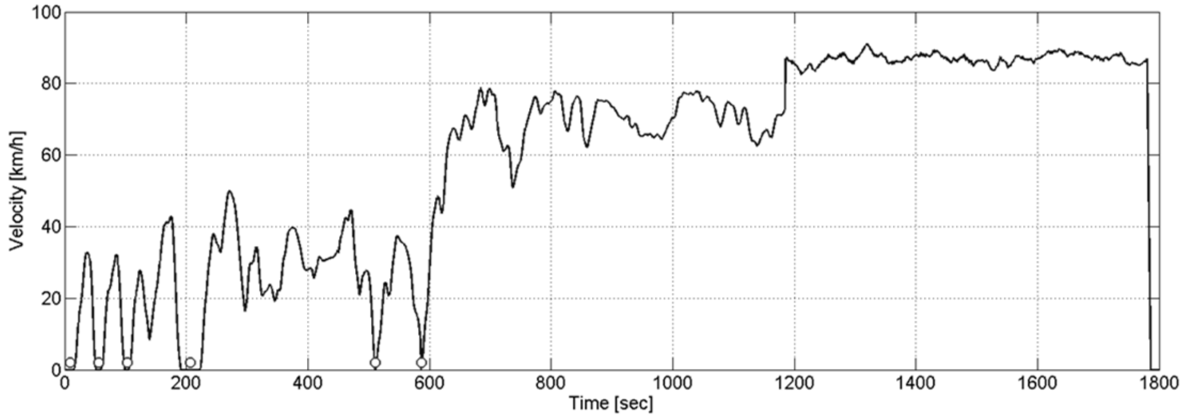

Figure 11: Start-and-stop in the ETC

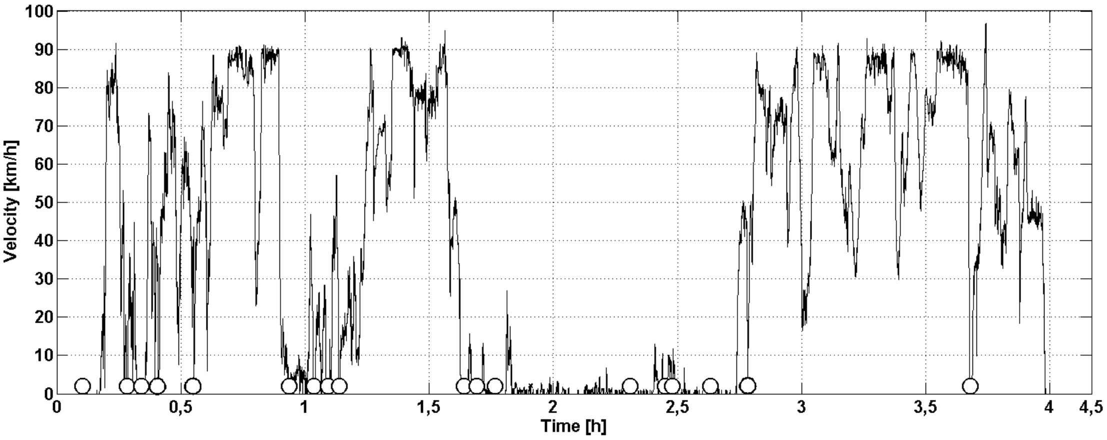

Figure 12: Start-and-stop in the real drive

COLLECT OF REAL LOAD CASES

For the developmental methodology a multi mixed database is necessary, if we want to build up different load cases of commercial vehicles. The goal will be to generate the generic load case out of true driving load cases. If the load cases will adapted prepared the authenticity will be lost. That brings the benefit of an anonymous evaluation.

We can offer different solutions to collect load cases. They all have their specific pros and cons. One way is to collect CAN (Controller Area Network) information. This information has a high resolution and quality of the data from the vehicle and all its components. Collecting data via CAN is expensive. Most load cycles are based on velocity and time. To collect this information, a simple GPS tracker will be enough. The price is lower and it is a lot easier to install them in different types of vehicles. So we decided to use that solution.
The GPS-tracker is and will be placed in vehicles with different purposes to collecting and recording the daily route. After a couple of weeks the storage of the GPS-tracker is full. The recorded files have to be read out. Afterwards it is possible to continue with this vehicle or to use another vehicle with a different purpose. So we record a database with a multifarious of individual and different driving purposes of real drives.
The collected data are including the velocity, position, elevation, time and number of the satellite. With this information the real load cases can be analyzed with the following explained methodology.

METHODOLOGY

The collected real load cases are in typical measured signals quality. First the quality has to prepare about system errors of the GPS tracker. Afterwards they can be analyzed by an innovative method in different ways. At the end several load components are saved in the storage for generating a load cycle kit. With them a special reference load profile of different application purposes can be generated.

Preparing the real load cases

The measured signals are noisy and have to be prepared. At first the signal validation will check the sum of the satellites. If there are not enough satellites, the current position is not exact and flawed with a high inaccuracy. These points are getting cleared and the remaining information are interpolated. The quality of the elevation from the GPS can't be used. For regenerate a new elevation profile the preparing using a high solution map from DLR (Shuttle Radar Topography Mission - SRTM). The elevation is one of the most interesting information for the new methodology. The driving resistant of the elevation can be the highest at a real drive.

The inaccuracy measuring at low velocity is the next problem. If the vehicle stands or moves very slow, the position is varied. The velocity is a function of the time and position. Cause the accuracy of the GPS signal is approximately 10m. A standing or slow moving vehicle has a velocity failure up to 4km/h. That can be solved with a filter. Therefore the filter recognizes if the position is still moving forward or backward, that means the vehicle is moving. But if the position is discontinuous, it is a sign for a standing car. These filtered information are added to the real load case and finalizing the preparing of the real load case. Now the load case analyzing can start.

Load case analyzing

How could a load case be analyzed? For the answer of this question, let's have a look on the different available load cases. So it's able to recognize the different velocities of the vehicle, i.e. how often the vehicles are accelerating, decelerating or braking. After this first overview the purposes of the vehicles can be identified. If the load of the vehicle is on a maximum, than how often or long the vehicle is driving with full load. But now have a look on the elevation, which is actually one of the most interesting parts. The potential energy of a 40t truck is a high parameter. Goal will be to evaluate all this information in a mathematical function to generate load components and information of the track for generating load cycle.

First the different between working and driving load cases have to be distinguished. For this purpose the driving is easy to evaluate. If the vehicle is moving, than it's a driving cycle case. But what will happen if the vehicle stands? That can be a traffic jam, traffic light or some other traffic hold-up, but also a vehicle that's in working mode. As long as delivering vehicles are standing the engine is off. But construction vehicle or agriculture vehicle are working while they standing with a running engine. First we have to decide what type of vehicle we are looking for. After that the time of standing will be evaluated. Is the vehicle's position still moving forward or backward or is the position is unsteadiness. Later on this gives a base for a statement, if the vehicle is working or moving.

In a second step the statistical frequency distribution will be used. The velocity will be analyzed. How often and how long is each velocity been used during the real load case? The vehicle runs in a good average or are there more used velocity parts for this purpose? The statistical frequency distribution of the slope of the load case is also been evaluated. For vehicles they run mostly the same velocity, the slope gives the only variation, if the route is uneven.

For the future conceptual and the preparing of the perfect control strategies of thermal and energy management the time of acceleration, deceleration and braking are the interesting point here. The numbers of acceleration, deceleration and braking times and length are necessary. A local consideration will be needed. If the vehicle is standing, how long takes it to accelerate up to special velocities? The acceleration from a special velocity up to a different one is important, for getting information about the acceleration behavior. Not only the times to accelerate the vehicle are interesting, but also the time for braking and decelerating. As well how often the vehicle has to brake and decelerate. That will be also necessary for generating a special load case. An additional interesting function is based on the numbers of Stop-and-go phases. All these information are needed for a future conceptual of the powertrain.

As like in power plant technology the purpose can be categorized in qualitative characteristics. We are looking for the base, average and peak load power of the vehicle. The peak load can show for e.g. an uphill drive. The base load power shows an empty driving truck. But they are giving only a qualitative statement. A mix of three categories can be possible as well. The average of each purpose is evaluated. That gives a base for the reference load case, how often each part has to been included.

Load components

After the real load cases are been analyzed, the methodology has to build up some load components for the database. Each real load case is analyzed with the methodology for built up bricks for a/the module kit. The information from the application purpose of the real load cases have to include. All cycles of each application purpose have to build up their own load profile. Goal will be to build up a database that confirms all this bricks and application load profiles.

Reference load profile

A special vehicle can be parameterized with a parameter variation. That means the input parameters from the assembling part of the methodology have to include information of the purpose, vehicle and tour.

With those parameters the fitting block from the module kit will be chosen. The methodology has to analyze how many blocks, which blocks and in what sequence the blocks have to use. Afterward the final assembling of the combine blocks generates a load and driving profile.

Reference load cycle for one application purpose from real load cases can be generated as well. This reference load cycle can be created with the sequential Monte Carlo method (SMC).

The above solutions for generating load profiles are just two examples, new strategies are going to be developed in the future. But we still have a solution for generating individual load and driving cycles with this methodology.

FURURE CONCEPTUAL

The generated reference load profile can be used for the basic statement of new control strategies and vehicle design. These load profiles are going to support the development of thermal- and energy management as the most important input parameter. A vehicle can perfectly adapt with a define load case. That means the strategy of the gear shifting or the recuperation times can be adapted to the individual vehicle.

The power and best type of the powertrain is calculated. Will the actuation a conventional engine or an electric hybrid. Rang extender and fuel cell actuation are also analyzed and designed for application as powertrain. If the powertrain is known, the individual control strategy can developed for finishing the energy management.

Additional the thermal management will develop. The climatisation is one of the big goals they have to solve in the common years, especially for batteries and hybrid vehicles. To use all lost heat or the exhaust.

To see how often real vehicles are braking the charging and recuperating of braking energy can be used if it brings a benefit for the fuel and energy consumption.

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