Driving Cycles Project

Final Report

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Background

A driving cycle is a representation of vehicle speed versus time, and in the automotive industry driving cycles have been used to evaluate vehicles both in the development phase of new vehicles, but also in gas emissions tests. Using fixed driving cycles there is a risk that the vehicle is optimized for a certain driving cycle, and if the driving cycle is not representative for real-world driving there is a considerable risk that it will be a sub-optimal solution for real-world driving. The objective is representative driving cycles sufficiently close to data from real-world driving.

One case of use of driving cycles is the sizing of powertrain components. For Hybrid Electric Vehicles the energy consumption, emissions and economic viability of the vehicle strongly depends both of the component sizing and on the use of the vehicle on real-world driving. Therefore driving cycles that correctly describe the use of the vehicle are of great importance for the sizing process.

General project description

The generation of representative driving cycles (part a of the project) is solved by a two-step-method where the first step is generation of candidate driving cycles using a Markov chains where the transition probabilities are estimated from real-world driving data. As a second step these candidate driving cycles are transformed to target statistical measures that can for example be that of real-world driving. The transformation of the driving cycles where formulated as an nonlinear programming problem and was solved by standard optimization techniques.

On the application side, driving cycles are used to sizing the battery and range extender of a Range Extender Vehicle (part b of the project). The objective is determining which driving cycles characteristics most influence the sizing of battery and range extender for Range Extender Vehicles.
Additionally we investigate the robustness of the battery size and range extender sizing towards changes in the driving and economical parameters.

The problem of finding an optimal battery size is formulated as an optimization problem, in which the Total Cost of Ownership of the vehicle is minimized. In the case of the range extender sizing both performance requirements and control strategies are considered when determining the optimal sizing.

Achieved results

The combination of the two driving methods yields a stochastic and general to generate driving cycles with certain properties that can be used during several stages during the vehicle development process of vehicles.

A clear description and relation of the main driving cycle factors influencing the sizing of battery and range extender for Range Extender Vehicles have been found. In the battery sizing case both an analytical and visual solution of the optimal battery size has been found, as well as for the economical sensitivity towards possible changes on the driving patterns or the economical. The results show the importance of the distribution of distance between charges when sizing the battery for Range Extender Vehicles.

In the case of the range extender sizing the results show that the sizing of this component is mainly dependent on the power requirements of highway driving and gradient driving as well as on the used battery discharging strategy. In the case of using a Charge Depleting-Charge sustaining strategy the size of the Range Extender is determined by the more demanding gradient driving. However in the case of using a predictive battery discharging strategy the Range Extender can be sized to only cover the less demanding highway driving.

Contribution to hybrid vehicle technology

A powerful and effective tool has been proposed that can generate driving cycles that have equivalence properties regarding vehicle excitation. For example, the sensitivity and robustness of the fuel consumption or battery sizing of a hybrid electric vehicle to the driving cycle can now be evaluated in more detailed since using the methodology different driving cycles can be generated with different amount of recuperation energy. At the same time other measures can be controlled in a much larger extent than it was possible before.

A deeper understanding of the driving cycle factors influencing the battery and range extender sizing has been achieved. A method and visual representation of the battery sizing based on real world driving data have been developed, which can be used to decide for the optimal battery size both for individual customers and for a large set of customer.

Uniqueness and news value

By formulating the transformation of driving cycles as a nonlinear programming problem enables general constraints to be considered in an optimization framework. A possibility is to also consider a cost function, for example vehicle jerk, to improve the drivability of the generated driving cycles. Combining this transformation with a driving cycle generation approach, for example the Markov chain approach, yields an easy to use and general framework to get new driving cycles that meet the requirements for the future vehicle design.

By studying on detail the sizing the battery and range extender we have been able to narrow down and extract the key driving factors determining the sizing of these components. Moreover the results also show the importance of designing driving cycles that aim at different parts of the sizing process, in which the key factors influencing the result represent real-world driving and can be modified.

Timing and finance

The total project budget is SEK 3038 kSEK million, 3038 kSEK of which is funded by SHC. (Part a: 2025 kSEK, Part b: 1013 kSEK). Duration: 2013-04-01-2015-06-30.

Executors and collaboration

Part a: Prof. Lars Nielsen (project leader, supervisor), Erik Frisk (supervisor), Peter Nyberg (PhD student), Linköping University.
Part b: Prof. Jonas Sjöberg (supervisor), Anders Grauers (supervisor), Victor Judez (PhD student), Chalmers
Reference group: Sören Eriksson, Volvo Car Corporation; Mathias Björkman, Scania; Sixten Berglund, AB Volvo

Dissemination of Results

Part a: Conferences: The Swedish Energy Agency Energy-related vehicle reseach October 8-9, Gothenburg, 2014. Reglermötet June 3-4, Linköping 2014. Workshop: Svea May 20, Gothenburg 2015, WS4 (in this project), May 25, Linköping, 2015.

Part b: "Economic sensitivity of the battery size selection for Plug-in Hybrid Electric Vehicles" To be summited to journal.

Papers and publications

Part a: "Driving cycle equivalence and transformation" Submitted to journal 2015, "Evaluation, generation, and transformation of driving cycles", PhD thesis, Peter Nyberg, 2015, To be defended on June 10, 2015 at Linköping University.

Part b: "Downsizing Possibilities of the Range Extender on a Range Extender Vehicle Using Predictive Information" Summited to IFAC Workshop on Engine and Powertrain Control, Simulation and Modeling.

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