System level evaluation of a hybrid drivetrain and after treatment systems in dynamic drive cycles

Drive cycle evaluation for hybrid drivetrains

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Summary

In this report dynamic drive cycles have been tested and evaluated using a hybrid drivetrain in a test rig. Studies have been made of conventional ICE operation and a strategy when the electric machine have briefly been evaluated to analyse the influence of emissions, by supporting the ICE. The strategy have only been using small amounts of energy during these tests. Load has been shifted from the combustion engine to the electrical motor. Good results have been made, Engine Out emissions peaks with NO was reduced from 2000 PPM to 500 PPM during cold start conditions and small torque split during transient operation. Chalmers have been the main conductor with support from Volvo Car Corporation.

General project description and background

Modern, efficient direct injected engines based vehicle drivetrains includes, besides the engine block, a turbo system for air management and an exhaust aftertreatment system (EATS) to limit the emissions. In a hybrid vehicle application the combustion powertrain is complemented with e.g. an electric motor/generator with electric energy storage capability. To obtain an efficient vehicle that minimizes fuel cost and obey legislative emission limits an overall control system is required. For hybrid applications the so-called power split control problem has been well studied in the literature for various load cycles including transient cycles. The efficiency of the EATS is highly dependent on the temperature in the catalysts. In the traditional, non-electrically heated, catalysts the temperature can only indirectly be influenced through the control of the combustion engine. In transient work cycles, where the combustion engine is operating at various loads, the after treatment system temperature and efficiency to reduce emissions will vary significantly. In hybrid applications, where engine shut-off is employed the situation is further pronounced. Efficient/optimal system level control strategies that explicitly accounts for the temperature effects are non-trivial for transient work cycles. Particularly there are several trade-offs between using different combustion modes (with a fuel penalty), using the electric motor (with a battery penalty).

In this project we propose to experimentally investigate the complete hybrid powertrain (including EATS) in the newly built hybrid rig at Chalmers. The objective is to collect data from the system; to enable control oriented models to be developed and a system optimization to be done. This data collection is vital as a platform for further studies. It will enable a strong collaboration within several departments, industry and research fields. The data collected can also be used in order to be used to evaluate aftertreatment models, as well for control design during simulation studies.

Achieved results

Studies and tests have been made focusing on the certification drive cycle NEDC analysing conventional certification methods according to ECE-R101. See Figure 1 for an example where the vehicle mass has been varied. Focus has also been made evaluating the performance in the more transient US drive cycle FTP-72.

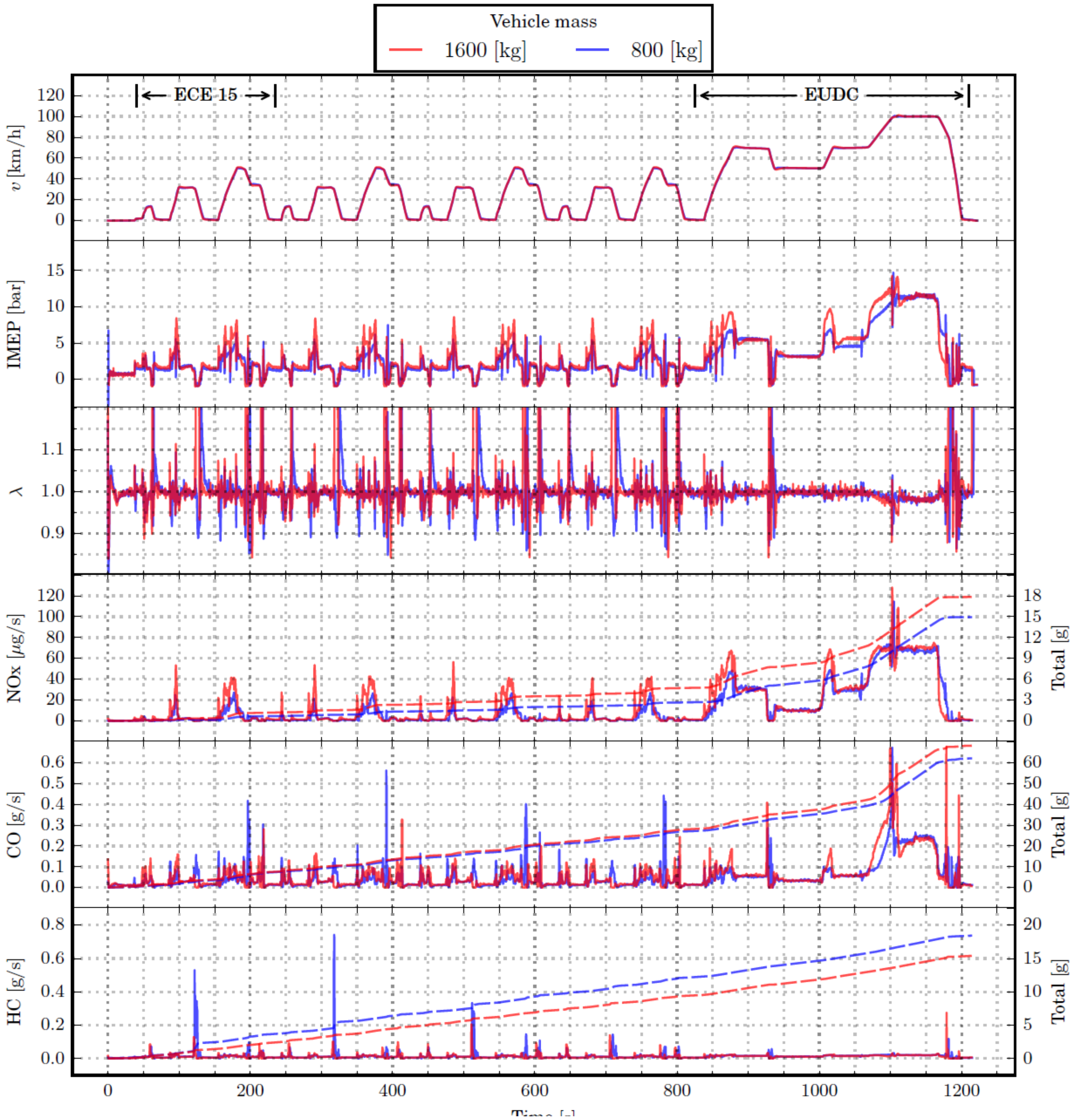

Figure 1 Representing a comparison between transient emissions tested with different vehicle mass. Solid line represents mass rates and accumulated emissions are represented as dotted lines in the figure.

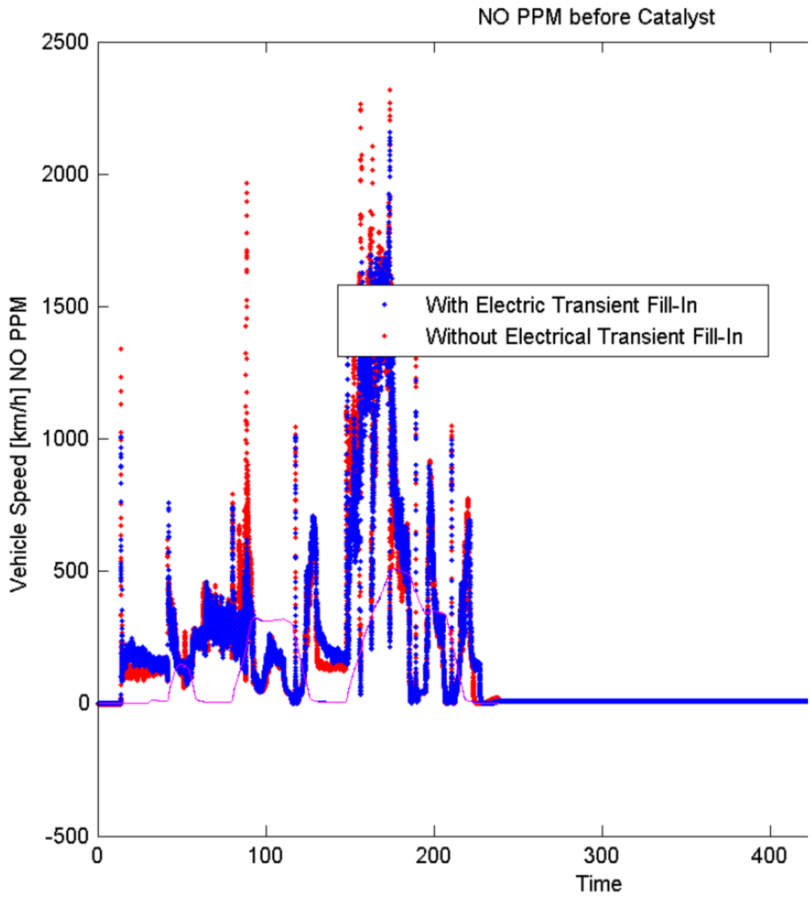

Figure 2. Engine out emissions (NO) before catalyst comparing strategies with and without electric torque fill-in

In Figure 2 we the results of engine out NO levels for the case with and without electric torque fill-in. Peaks of NO are reduced from 2000 PPM to 500 PPM before catalyst during small transients at second part of the ECE 15 cycle. During the third part emissions are reduced from 2400 PPM in peak to 1700 PPM.

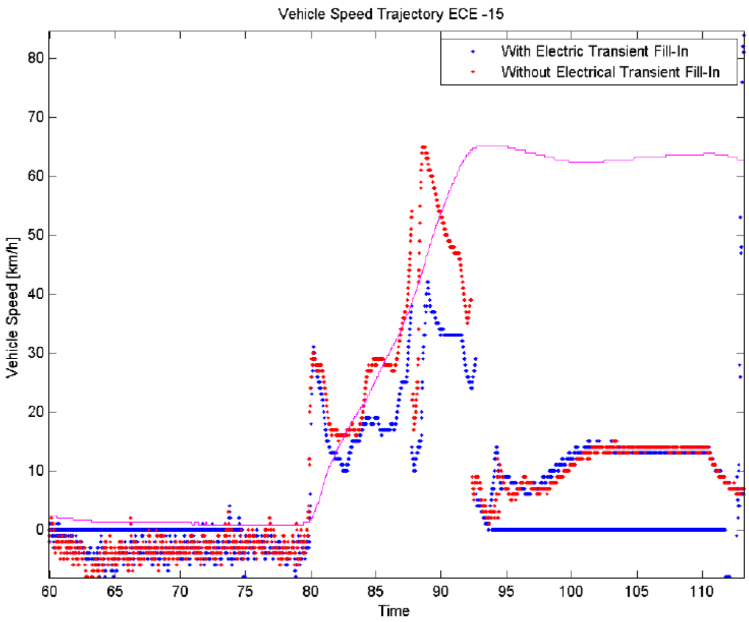

Figure 3 Providing information of the strategy to reduce peaks in Crankshaft Torque but remaining at constant load during stationary driving

Figure 3 illustrates the effect of using the electric machine to reduce torque peaks on the crankshaft at constant load and stationary driving. As can be seen in the figure the crankshaft peaks are reduced with electrical boosting. Crankshaft peaks are reduced from 70 Nm to 40 Nm which is mainly conducted during shifting sequences and engine speed control.

Timing and finance

Project is executed from 2015-01-01 until 2015-06-30 and is comprised of a measurement campaign in the Chalmers hybrid test rig and data analysis.

The total project budget is SEK 350 kkr, of which 300 kkr is funded by SHC.

Executors and collaboration

Volvo Car Corporation has been supporting with Software support, calibration support and test Software. Chalmers has carried out the testing and emission measurements.

Dissemination of Results

Results from the study will be prepared as a report and will be submitted for publication.

Papers and publications

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