Evaluation of energy efficient cornering strategies using the KTH Research Concept Vehicle

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Summary

Reducing vehicle energy consumption is a key issue for the vehicle manufacturers as well as for the consumers and an important aspect for our environment. The introduction of more advanced drive systems will allow vehicles to be implemented with multiple electrical actuators enabling over-actuation. These actuators open up for new and cost-efficient solutions for motion control, which makes it possible to develop vehicle control strategies for enhanced energy efficiency without compromising comfort and safety.

The aim with this project is to study and develop energy-efficient cornering strategies for electrified vehicles with different degrees of active control of the propulsion and steering, as well as evaluate these strategies by using the KTH Research Concept Vehicle (KTH RCV).

A simulation environment for development and evaluation of energy efficient cornering strategies using over actuation have been developed. Simulations for different types of manoeuvres (double lane change, single lane change and steady-state cornering) and parameter settings have been performed and analysed. It is found that it is possible to improve the energy efficiency in the order of 1 - 5 % during cornering with the developed cornering strategies. Simplified cornering strategies are now prepared for implementation in the KTH RCV to experimentally evaluate their energy efficiency.

The project has been performed during the period October 2014 – June 2015, with a funding of 325 kSEK from SHC.

General project description and background

Due to increased environmental awareness and for economic reasons energy efficient driving is of high importance. Introduction of more advanced drive systems will allow vehicles to be implemented with multiple electrical actuators enabling over-actuation. An over-actuated vehicle has higher number of control outputs than required to control a given number of degrees of freedom. These actuators open up for new and cost-efficient solutions for motion control, which makes it possible to develop vehicle control strategies for enhanced energy efficiency without compromising comfort and safety.

The overall aim with the project is to study and develop energy-efficient cornering strategies for electrified vehicles with different degrees of active control of the propulsion and steering, as well as evaluate these strategies by using the KTH Research Concept Vehicle (KTH RCV).

The research work is based on the preliminary findings in the now finished SHC-project "Generic vehicle motion modelling and control for enhanced driving dynamics and energy management".

The plan of the project is to develop a simulation environment in MATLAB for evaluation of energy efficient cornering using over-actuation. This means evaluate and improve previous developed models and implement new test manoeuvres. After performing the simulations, simplified control strategies are identified for implementation in the KTH RCV.

Achieved results

A simulation environment for evaluation of energy efficient cornering using over-actuation has been developed. Within the simulation environment three test manoeuvres have been evaluated; double lane change, single lane change as well as steady-state cornering. Different torque vectoring and rear axle steering algorithms have been tested. The simulations, including a parameter study, have shown energy efficiency improvements of 1 - 5 % during cornering. Simplified control strategies that are realistic to implement in a real vehicle have been identified and are to be evaluated in the KTH RCV during autumn 2015 at the test facility AstaZero.

Vehicle energy efficiency is a key issue for vehicle manufacturers since the buyers require low energy consumption and thereby it is a competitive tool between different brands in order to sell their produced vehicles. There are also demands from authorities as well as the society to reduce the CO_2-emissions.

After evaluating the energy efficient control strategies, the intention is to combine this knowledge with the knowledge from another research project that focus on developing a tyre model to be used in the development of control strategies for reduced rolling resistance. That project is financed by the Centre for ECO^2 Vehicle Design. By combining the knowledge from these two projects larger energy savings are anticipated.

Timing and finance

The research has been performed by dividing the work into the following work packages:

- **WP1**: Evaluate and improve the previous models developed within the SHC-project "Generic vehicle motion modelling and control for enhanced driving dynamics and energy management" (October – December, 2014)
- **WP2:** Development of simulation environment (including vehicle model, road model and driver model). Identify and model new manoeuvres (January - February, 2015)
- **WP3:** Evaluate and analyse the simulation results for different parameters settings (February - June, 2015)

The total project budget is 485 kSEK, of which 325 kSEK is funded by SHC.

Executors and collaboration

Jenny Jerrelind has been the project leader and thereby wrote the application, planned the work and was responsible for the deliverables of the project.

Johannes Edrén, Lars Drugge and Jenny Jerrelind jointly developed and theoretically evaluated different energy-efficient control strategies. Johannes Edrén developed the simulation environment in MATLAB.

An application to Vinnova and FFI – AstaZero has been approved (June 2015) to finance 3 days of tests with the KTH RCV at the test facility AstaZero. The total budget of the FFI-AstaZero project is 750 kSEK of which 375 kSEK is funded by Vinnova. Jenny Jerrelind and Lars Drugge wrote the application.

Dissemination of Results

The results have been disseminated through participation in the following activities:

- SHC conference, June 4, Gothenburg, 2015.
- SVEA conference, Vehicle Dynamics Seminar, May 20, Gothenburg, 2015.
- Volvo Cars meeting regarding control strategies for reduced energy consumption, April 27, 2015.
- SHC cross-thematic and doctoral student network meeting, 11-12 March, Hallsberg, 2015.
- PhD-thesis defence by Johannes Edrén, December 3, 2014.
- Based on the final results of this research project a scientific article will be written and published.

Papers and publications

[1] J. Edrén, M. Jonasson, J. Jerrelind, A. Stensson Trigell and L. Drugge, *Energy efficient cornering using over-actuation*, submitted for publication, 2015.

[2] J. Edrén, *Motion modelling and control strategies of over-actuated vehicles*, PhD thesis, TRITA-AVE, 2014:75, KTH Royal Institute of Technology, December, 2014.

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