Model for simulation of driving behaviour during failures in electrified vehicles

Lars Drugge
Associate Professor, KTH Vehicle Dynamics

Swedish Hybrid Vehicle Centre
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Summary

A driver model has been developed that can represent the driving behaviour during failures in electrified vehicles. The model is based on measurements of human responses when exposed to different failure conditions influencing vehicle directional stability. The developed driver model is building on the findings in the finalised SHC-project “Fault-tolerant over-actuated hybrid electric vehicles”, which had the aim to analyse the impact of failure modes and find suitable fault-tolerant control strategies in electrified vehicles, in order to gain knowledge of driver-vehicle interaction during a failure.

The aim has been to design a failure sensitive driver model using parameters derived from experiments in a moving-base driving simulator performed within the ERA-NET Electromobility+ project EVERSAFE, where the subjects were exposed to sudden failures in one of the rear wheels that required adequate corrective measures to maintain the vehicle control and regain the planned trajectory.

The developed driver model has been used in a simulation environment to evaluate the influence of failures in electrified vehicles. The results show that the proposed failure-sensitive driver model is capable of maintaining the vehicle control and regaining the planned trajectory similarly to the way in which humans achieved this during a rear wheel hub motor failure. Furthermore the model has been used to analyse the influence of fault-tolerant vehicle dynamic control strategies on the driver-vehicle interaction using the Research Concept Vehicle (RCV) at KTH. Finally, the modelling and evaluation of the driver model have been documented in a scientific publication accepted for publication in the proceedings of FAST-zero´15.

The project has been performed during the period 1 October 2014 – 30 June 2015, with a funding of 210 kSEK from SHC.

General project description and background

The complexity of electrified vehicle components and subsystems has been increasing in recent years and this is a development which at present seems to be continuing in the same manner. One consequence of this complexity is that a larger amount of faults can occur in a vehicle, leading to the increased probability of a failure occurring. Specifically, there is a greater risk of failures affecting the dynamic behaviour of vehicles and endangering traffic safety.

Today driver models are an important tool in the development of vehicles and are a substitute for experimental tests to a greater extent. However, existing driver models have not been evaluated on their capability to handle an unexpected event, such as a failure of a wheel hub motor, in the same manner as a human and at the same time are based on real driver data. The purpose of the project is therefore to develop a driver model that can represent the driving behaviour during failures in electrified vehicles based on real life data from experiments.

The plan is to design a failure sensitive driver model using parameters derived from experiments in a moving-base driving simulator performed within the ERA-NET Electromobility+ project EVERSAFE. In the simulator study, the subjects were exposed to three sudden failures in one of the rear wheels that required the driver to compensate to maintain vehicle control and regain the planned trajectory. A co-simulation environment with Matlab/Simulink and Dymola is used for the driver model as well as for the failure implementation and activation.

The goal is to create a driver model that can be used in a simulation environment to analyse the influence of various failures without the need of costly, dangerous and time consuming experimental tests. Fault-tolerant vehicle dynamic control strategies and alternative traffic scenarios or driving manoeuvres can be evaluated correspondingly. The results will also be documented in a scientific publication.

Achieved results

A failure sensitive driver model (FSDM) has been developed. The FDSM shows promising results for the analysed failure conditions, being capable of maintaining the vehicle control and regaining the planned trajectory similarly to the way in which humans achieve this during a wheel hub motor failure in one of the rear wheels [1]. The potential of imitating different types of driver behaviour by adjusting the failure-sensitive parameters has also been shown. Furthermore the model has been used to analyse the influence of fault-tolerant vehicle dynamic control strategies on the driver-vehicle interaction using the Research Concept Vehicle (RCV) at KTH with promising results [2].

Driver models are an important tool in the vehicle development and substitute experimental tests to a large extent. In combination with appropriate vehicle simulation models, driver models can be used to analyse, adapt and validate vehicle dynamic behaviour prior to and in the prototype phase. The result of this project is the first step to develop a computational approach to predict driver-vehicle performance when the vehicle is exposed to a sudden failure. This approach gives new possibilities to evaluate vehicle's sensitivity to failures in the early design stages in the product development, without the timely and costly building of prototypes.

Timing and finance

The research has been performed within the following work packages:

- **WP1**: Implementation and evaluation of common preview driver model and development of simulation environment within Matlab/Simulink and Dymola (Oct-Dec 2014).
- **WP2:** Development and evaluation of failure sensitive driver model with features such as reaction time, synchronisation time and additional time delays, based on human reactions to different sudden failure modes influencing the vehicle directional stability (Jan-Apr 2015).
- **WP3:** Evaluation of the driver model in a simulation environment using the KTH RCV with and without a fault-tolerant control system and verification with results from field tests including driver in the loop (May 2015).
- **WP4:** Writing of scientific publication to FAST-zero 2015 (Feb-June 2015).

The total project budget is 290 kSEK, of which 210 kSEK is funded by SHC.

Executors and collaboration

Lars Drugge has been the project leader, which includes writing of application, planning the work and being responsible for the deliverables of the project. Daniel Wanner and Lars Drugge developed jointly the vehicle and driver model, performed the simulations, conducted the analysis and wrote the paper. Johannes Edrén developed the road model

and provided valuable comments. Annika Stensson Trigell provided useful ideas and proofread the paper.

The proposed driver model is a collaboration with, and extension of, the SHC-project "Fault-tolerant over-actuated hybrid electric vehicles" which had the aim to analyse the impact of failure modes and find suitable fault-tolerant control strategies in electric and hybrid-electric drivelines, in order to gain increased knowledge of driver-vehicle interaction during a failure.

The project has also a sister SHC-project, "Testing and evaluation of fault handling strategies in the research concept vehicle", where fault-tolerant control strategies were implemented and experimentally evaluated using the RCV.

Dissemination of Results

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

- SHC cross-thematic and doctoral student network meeting, 11-12 March, Hallsberg, 2015.
- Scania-meeting regarding coupled simulation of vehicle dynamics and aerodynamics of heavy vehicles and the influence of driver-vehicle interaction, 13 May, Södertälje, 2015.
- SHC conference, 4 June, Gothenburg, 2015.
- PhD thesis presentation by Daniel Wanner, 5 June, Stockholm, 2015.
- The project results will also be presented at the FAST-zero´15 Symposium, September 9-11, Gothenburg, Sweden, 2015 [1].

Papers and publications

[1] D. Wanner, L. Drugge, J, Edrén and A Stensson Trigell, *Modelling and experimental evaluation of driver behaviour during single wheel hub motor failures*, Accepted for publication in proceedings of FAST-zero´15, the 3rd International Symposium on Future Active Safety Technology toward zero traffic accidents, September 9-11, Gothenburg, Sweden (2015).

[2] D. Wanner, *Controlling over-actuated road vehicles during failure conditions*, Doctoral thesis in Vehicle Engineering, TRITA-AVE 2015:23, KTH Royal Institute of Technology, Stockholm, Sweden (2015).

Swedish Electric & Hybrid Vehicle Centre
Chalmers University of Technology
Hörsalsvägen 11, level 5
SE-412 96 Göteborg

Phone: +46 (0) 31 772 10 00
www.hybridfordonscentrum.se