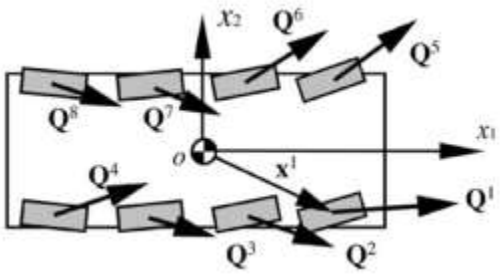
FFI

Traction Control



Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

This project is aimed at improving traction control characteristics for wheel loaders and haulers. At present, drivers of these machines can choose between open or closed differentials but often they prefer to lock the differentials, thus distributing the torque equally between the wheels and thereby almost always avoiding wheel slip. However, locked differentials cause increased wear of the driveline, increased fuel consumption and greater tyre wear. The project investigates a few technical solutions and primarily the control of these to reduce wheel slip.

The project is to be led by Volvo Construction Equipment AB in cooperation with Luleå University of Technology. The results are used by Volvo CE as input to future machine control systems and by LTU in building equipment and competence for further research and undergraduate education in the area. The project is supported by 2 PhD students and senior researchers from LTU and by several machine prototype development projects at Volvo CE with LTU interaction being coordinated by the project leader.

The project has studied the effect of many parameters on wheel slip and needed propulsion power and has implemented control strategies based on this knowledge in a construction machine. The project has also tested ways of identifying the slip affecting parameters during machine operation.

2. Background

Tire wear is a major cost for construction machine owners and has an impact on the environment. Both tire wear and fuel consumption can be reduced significantly by proper driving behaviour. But, the wheel torque control can also be implemented such that these factors are decreased, especially in the case of hub motor solutions - such as in the Gryphin concept machine - where there is a large degree of control freedom.

3. Objective

The control of wheel torque affects tire wear and fuel consumption, especially for offroad machinery and offroad vehicles and there is a large chance to decrease both factors in the case of hub motor solutions. The project aims at gaining knowledge on how operating conditions affect the optimum setup of the control strategies using both analysis and

physical tests. The project also aims at implementing the control strategies in Volvo CE prototype machines such that the knowledge gained reaches the end customers in the end.

4. Project realization

The project started in the second half of 2009 with Gianantonio Bortolin as the project manager at Volvo CE. The initial work was focused on haulers. Johan Markdahl as a Master's thesis project did the first work in the project. Johan did a simulation study and continued to work for Volvo during the spring of 2010. Johan presented his ideas regarding traction control of the hauler at the "Reglermöte 2010" in Lund.

In October of 2009, Ulf Andersson started working in the project as a PhD student at Luleå University of Technology. During Johan Markdahls work, it became clear that the so called side slip that occurs when turning could be important to estimate as a part of a traction control scheme. Ulf's initial work was then to measure the slip using a GPS/INS system on a hauler. For that reason, Fredrik Broström who later became the second PhD student in the project developed special software for logging data. The method used for estimating the side slip angle was presented at the SAE 2011 Commercial Vehicle Engineering Congress in Chicago.

In the beginning of 2011 Volvo CE decided to shift focus. The new focus became traction control for off-road articulated vehicles with individual wheel drives. Fredrik Broström started as the second PhD student at Luleå University of Technology in April 2011 with focus on upgrading the scale model articulated electric vehicle ArtiTRAX so that torque control of each drive was possible. Martin Karlsson did the first upgrade of ArtiTRAX in a Master Thesis project during 2010. In that work, ArtiTRAX was equipped with encoders and a PC104 computer. The origin of ArtiTRAX was a student project in 2006 at Luleå University of Technology in which two TRAX wheelchairs from Permobil was connected to each other via a joint and thus making ArtiTRAX articulated.

An activity that has run in parallel to the work described above is the wheel loader (L110G) that Volvo CE has based at Luleå University of Technology. The idea is that the wheel loader shall be used in different project, for instance in the traction control project. To get easy access to the sensors, actuators and CAN bus on the wheel loader; Fredrik Häggström has developed the so-called EBU system. EBU stands for electronic breakout unit. The EBU does not interfere with the original electronic control system (ECU) of the wheel loader. An EBU is connected to the wiring that originally is connected to the ECU. A special cable kit is used to connect the ports of the ECU with the EBU. The first project with the L110G was the student project course in electronic systems in the second half of 2012.

From 2011 and onwards, Volvo CE implemented a range of control strategies for individual wheel motor torque control for low energy consumption and low tire wear based on the knowledge gained in the Luleå Technology University activities.

5. Results and deliverables

Simulations and validations of traction control performances have been done on vehicles with mechanical driveline.

Scale-model tests have been performed on an articulated vehicle with individual (electric) wheel drives.

Extensive literature studies have been performed, both in public documents as well as in internal working reports. The conclusion is as in the application that little is reported that related to off-road articulated vehicles.

An important conclusion from the work relating to individual wheel drives is that the optimization criteria's of the traction controller has to consider the operating condition. Some operating conditions do not require maximum tractive force, in these cases optimizing conditions such as fuel efficiency and minimal tyre wear is of greater importance.

Volvo CE has implemented a range of control strategies for individual wheel motor torque control for low energy consumption and low tire wear based on the knowledge gained in the Luleå Technology University activities.

A PhD dissertation is planned as a result of the project in December of 2013

5.1 Delivery to FFI-goals

A well-tuned traction control is an enabler for individual hub motor vehicles and is important for the fuel efficiency and safety of such vehicles. This demands innovative solutions such as estimation of tire-ground slip conditions. The project has shown how to estimate such parameters during operation. The traction control also affects operability which through this project has increased the technology readiness level for the individual hub motor solutions being studied at the company.

The results are applicable to any industry with products where the drive shaft torques can be controlled individually, for example through limited slip clutches.

6. Dissemination and publications

6.1 Knowledge and results dissemination

Hub motors is a hot topic in the off-road industry and traction control is an important building block in achieving a good hub motor complete solution. The spread of results therefore occur naturally.

A number of publications have been produced in the project (see section 6.2). Luleå Technical University has also produced a large number of internal reports from thesis works, student projects and from the PhD students.

The project has been presented at the Volvo Construction Equipment PhD days in Eskilstuna, Sweden, May 16-17, 2011 and May 8-9, 2012.

Results from the project were presented at the SAE Commercial Vehicle Engineering Congress, September 13-14, 2011 in Chicago, USA.

6.2 Publications

Albertsson, K., Axelsson, H., Bohman, D., Bosquet, Charléty, S., Corazza, N., Desille, R., Diallo, F., Eble, O., Golob, G., Jasa, J., Monzón-Catalán I., Nilsson, J., Nyberg, R., Rönnbäck, O. and Vaumourin, G. (2013) *Volvo L110G Wheel Loader Automation*, Student project report, Luleå University of Technology, Luleå, Sweden.

Andersson, U., Broström, F. and Gustafsson, T. (2013) Tyre Parameter Estimation Based on Control of Individual Wheel Drives, *International Journal of Vehicle Autonomous Systems*, Submitted June 14, 2013.

Andersson, U., Bortolin, G., Backén, S. and Gustafsson, T. (2011) Estimation of Sideslip Angles of a Volvo A25E Articulated All-Wheel Drive Hauler Based on GPS/INS Measurements, *SAE Technical Paper Series 2011-01-2156*, Commercial Vehicle Engineering Congress, September 13-14, 2011, Chicago, Illinois, United States.

Häggström, F. (2012) *Electronic Breakout Unit*, Master's Thesis, Luleå University of Technology, Luleå, Sweden.

Markdahl, J. (2010a) *Traction Control for Off-Road Articulated Vehicles – A Simulation Study*, Master's Thesis, KTH Royal Institute of Technology, Stockholm, Sweden.

Markdahl, J., Bortolin, G., and Andersson, U. (2010b) Traction Control for Off-Road Articulated Vehicles, *Proceedings Reglermöte*, Lund, Sweden, June 2010.

Karlsson, M. (2010) *ArtiTRAX II*, Master's Thesis, Luleå University of Technology,

Luleå, Sweden.

7. Conclusions and future research

The optimization criteria's of the traction controller has to consider the operating condition. Some operating conditions do not require maximum tractive force, in these cases optimizing conditions such as fuel efficiency and minimal tyre wear is of greater importance.

A natural next step is to implement and demonstrate traction control in wheel hub motor solutions.

8. Participating parties and contact person

Contact persons

Volvo Construction Equipment AB
Anders Fröberg
016-541 6413
Anders.froberg@volvo.com

Luleå Technical University
Prof Thomas Gustafsson
0920-491323
Thomas.gustafsson@ltu.se

Project team

Volvo CE

- Gianantonio Bortolin.
- Henrik Berghäll.
- Rikard Mäki.
- Jonas Larsson.
- Anders Fröberg.
- Johan Markdahl (part time).
- Fredrik Häggström (part time).

Luleå University of Technology

- Thomas Gustafsson, supervisor.
- Ulf Andersson, PhD student.

- Fredrik Broström, PhD student (from April, 2011).
- Staffan Backén (part time, working as GPS expert during tests with the hauler).

Master's Thesis workers

- Johan Markdahl, KTH, 2009-2010.
- Martin Karlsson, LTU, 2010.