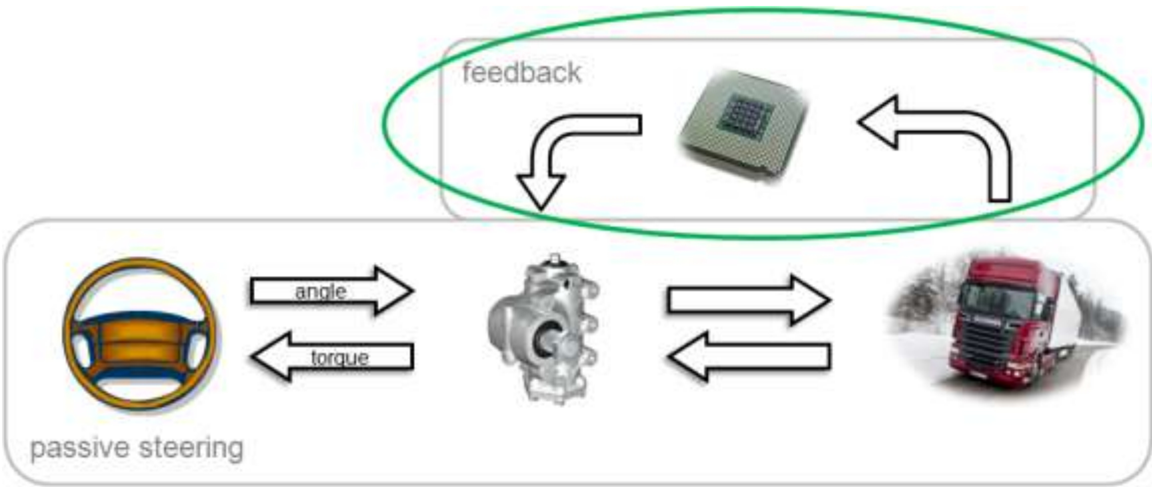
FFI

Steering system with active safety in heavy vehicles



Project within Vehicle and road safety

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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

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1. Executive Summary

The project's objective was to explore the truck unique opportunities for active steering in order to improve road safety. Active steering in this project has been either angle overlay where the system can affect how much the wheels move independently of the driver's steering wheel input or torque overlay where the system can affect the torque a driver feel in the steering wheel. The project has had access to a torque overlay prototype and tried – unsuccessfully - to build an angle overlay prototype.

For these two main principles of active steering, the project has developed various safety enhancement algorithms: Roll Over risk indication through steering torque and artificial understeer with the angle overlay. Both are unique for heavy vehicles in that roll-over is a typical phenomenon for trucks and truck tires usually show a tendency to shift to oversteering at higher lateral acceleration. Both features have been developed in software environment and look promising.

Only roll-over risk indication has been tested in a real truck and a series of test trails with different drivers has been conducted. The trails have shown that it is possible to influence driver behavior using the steering feel. Through the reduction of the torque to with the increase in lateral acceleration when the car approaches the rollover limit, the driver will reduce his speed in the curve. This ought reasonably reduce the risk of roll-over accidents.

The artificial understeer function, which requires angle overlay, could not be tested physically since the prototype could not be completed before the end of the project. The theoretical simulations, however, suggest that there is potential too. This will possibly be the subject of further investigation after this project.

2. Background

Road safety in the automotive industry has historically been strongly associated with passive safety: introduction of seat belts, improved crashworthiness and development of airbags. With the entry of more and more electronics in our vehicles, there is also an increased opportunity to judge the surrounding environment and to act by taking over some driving tasks as braking and steering to avoid an accident.

In the automotive industry active control has been initiated both angle overlay[1] and torque overlay[2]. Once the hardware is in place functionality grows in these systems as more sensors find their way into the cars. Initially Electronical power-steering (EPS) systems replaced hydraulics in power steering, then with the help of a rearview camera automatic parallel parking was realized and is now using the camera in the front window to make corrections when the car is about to leave the road.

Within the commercial vehicle industry, it takes more time to get the hardware in place, but the technology is finished as some system supplies have demonstrated publicly. It is reasonable to assume that systems will also evolve in complexity in similar manner as passenger cars. However, it is not as obvious that car functions will work equally well in a heavy vehicle. Moreover, there are some unique safety challenges for heavy vehicles, such as roll-over.

Furthermore, previous research has shown that drivers of heavy vehicles sometimes react differently than the average passenger car driver thanks to their significantly greater driving experience. An example is a simulator trial with an early warning system for driver drowsiness, built on registering drivers eye winks. The system worked very well in passenger cars but not among professional drivers. These showed an ability to "sleep with their eyes open." Similarly, professional drivers may use steering feel to drive the vehicle in another way.

[1] E.g. BMW and Audi
[2] E.g. VW

3. Objective

The project has aimed to research on truck unique safety functionality for active steering. Two basic problems have been attacked; indication of rollover risk by providing better feedback in the steering wheel and artificial understeer.

Roll-over Risk Indication

Heavy vehicles have a high center of gravity relative to their axle width and this increases the risk of rolling over when cornering at speed. The driver has an opportunity to minimize the risk by adjusting the speed but heavy vehicles lack a direct feedback from the approach of the roll-over limit. Drivers adjust the curve speed relying on their driving skills by perceived lateral acceleration, roll angle and steering torque.

The purpose of a function for roll-over risk indication is to investigate whether it is possible to actively influence the driver through the steering wheel torque.

Artificial understeer

Most heavy vehicles are equipped with different tires on the front and rear axles to meet the various requirements of the tire life and grip. Especially in the winter time, it is common with soft drive axle tires for better traction. This leads to reduced understeer of the vehicle which generally slows down the vehicle response to steering input and gives a nervous steering response; small hand-wheel movement gives a strong but delayed response in the vehicle which can be tiresome for drivers. Using angle overlay it is possible to define a function that counteracts the negative effects of soft rear tires, so-called artificial understeer.

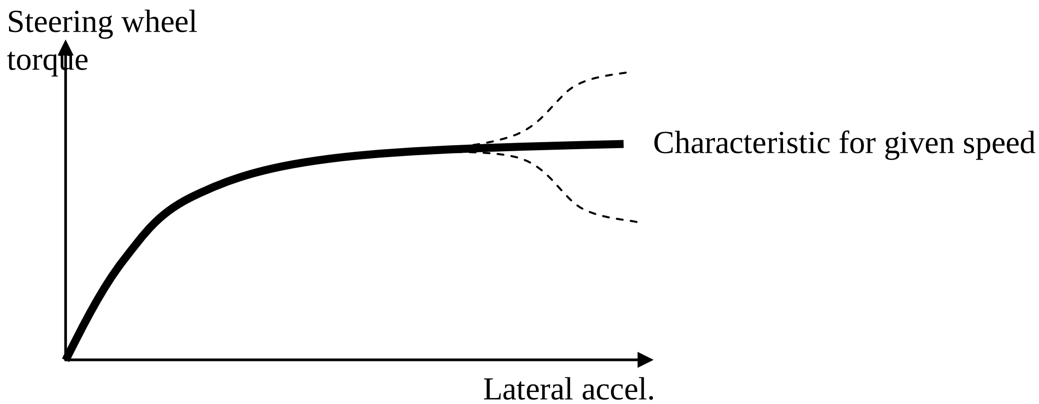
The purpose of artificial understeer is to investigate whether drivers perceive this vehicle in the same manner as naturally understeered vehicles.

4. Project realization

Roll-over Risk Indication

The project had a hardware prototype for torque overlay at its disposal in a test vehicle. The algorithm affected the steering wheel torque as a function of the vehicle's lateral acceleration in two variations by adding or subtracting elements, see Figure 1.

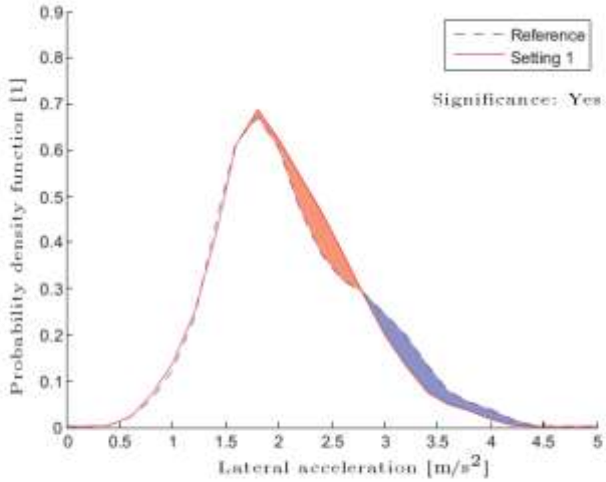
Figure 1 Principle of roll-over risk indication algorithm



The algorithm was developed using computer simulation where it was verified before a driver's test on a test track. With the algorithm in a vehicle different drivers conducted a blind test with and without the feature. The task was to run repeated laps on a fixed track with different settings in the algorithm. During the run vehicle speed and lateral acceleration were recorded. Afterwards lateral acceleration and vehicle speed were analyzed in the same curves.

The results in Figure 2 show that the maximum lateral acceleration decreased by a characteristic that gets lighter near the roll-over threshold. However, the tests also indicated that most drivers subjectively disliked the "ice patch feeling" and felt less confident with it. It remains to be seen whether the effect is long lasting and if this philosophy can be combined with the carmaker's general desire to communicate confidence with their products.

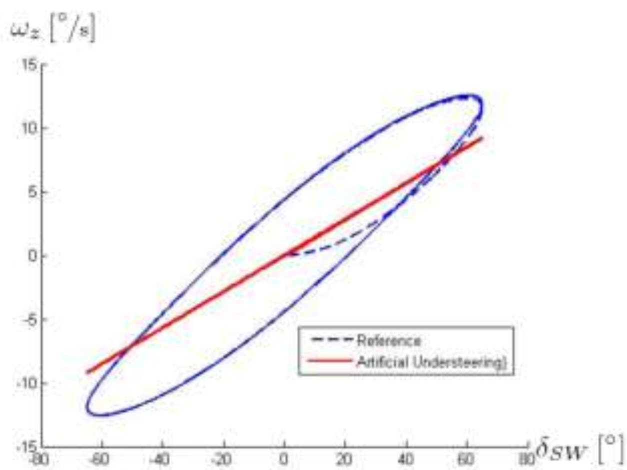
Figure 2 Distribution of lateral acceleration peaks with and without rollover limit indicator



Artificial understeer

This function requires an angle overlay prototype which was exclusively developed for this project. The prototype could not be completed within the timeframe of the project because of the difficulty of getting an external control engine to communicate with other electronic controllers in the car. Although the prototype is 95% complete it was impossible to carry out some driving experiments. The algorithm was developed in which the computer simulation showed to provide good response times despite the soft tires, see Figure 3. The work has resulted in a conference paper at a scientific conference.

Figure 3 Yaw respons of a car with the soft rear tire, with and without artificial understeer



5. Results and deliverables

5.1 Delivery to FFI-goals

The program for vehicle and traffic safety will support:

• Technology development with the potential to account for a third of the reduction in the number of fatalities as Parliamentary interim targets for 2020 are.

• The Swedish automotive companies remain world leader in the development of safe vehicles and vehicle safety

The project has contributed to an increased focus on active steering in the Swedish automotive industry through participation at various Swedish seminars. Even internationally, the debate has been affected by participation in scientific conferences - without speakers there will be no debate.

For Scania, the project has resulted in a survey in the field of active steering and the tests with a functional demonstrator has raised the know-how within the organization, both in practical and theoretical sense. Scania is now majority-owned by Volkswagen and has strengthened its position within the group when it comes to active steering. The project will likely be continued in cooperation with the Volkswagen Group Research.

6. Dissemination and publications

6.1 Knowledge and dissemination of results

In order to apply the knowledge in a commercial solution requires hardware development.

6.2 Publications

Rothhämel, M., IJkema, J. & Drugge, L.: Influencing driver chosen cornering speed by means of modified steering feel, submitted for publication.

Rothhämel, M., IJkema, J. & Drugge, L.: Artificial understeer by means of active steering an investigation of proper handling test methods, accepted for the 23rd International Symposium on Dynamics of Vehicles on Roads and Tracks, Qingdao, China, August 19 - 23, 2013.

Patent pending: Rothhämel, M.: Method for artificial understeering and acceleration of vehicle reaction (1250406-4).

7. Conclusions and future research

The project has shown that it is possible to influence driver behavior by means of steering feel and driver will run slower if the steering torque becomes lighter when approaching the vehicle stability limit. At the same time the driver experiences this as an unsafe vehicle. It remains to be seen whether this effect is long lasting and if manufacturers will adopt the principle that makes their vehicles feel insecure.

The project has shown that it is possible to eliminate the negative effects of soft rear tire with the angle overlay. For practical reasons, it has not been possible to test this in the car, and the question remains whether drivers perceive artificial understeer in the same way as natural understeer.

8. Participating parties and Contact person

The project has mainly been driven by Scania CV AB academic record from KTH Department of Vehicle Engineering.

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