Gear alternation

An article remarking upon the important results from a thesis work at ZF

Introduction

Company facts

This thesis work is performed at the company ZF Friedrichshafen AG. ZF is one of the world's largest manufacturers of parts for the automotive industry. They produce parts such as transmissions, steering systems and axle components to mention a few.

Problem description

The task of this thesis was to design a supplemental control algorithm to the existing drive line strategy that is used in the ECCOM[1] gearbox series. An example from the ECCOM series can be viewed in figure 1. The ECCOM is an automatic gearbox

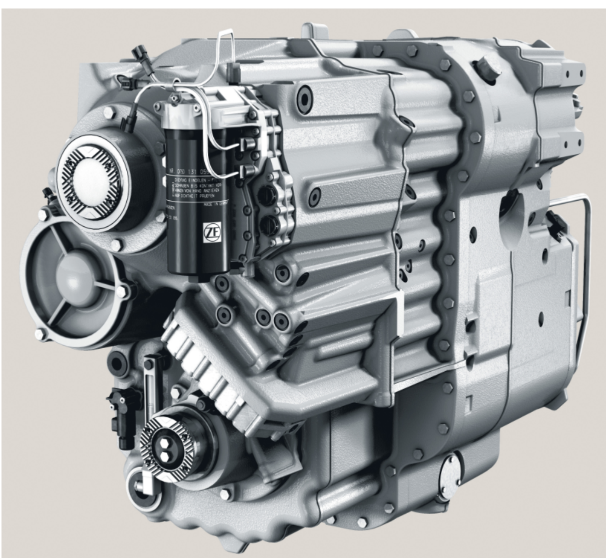

Figure 1: ZF ECCOM 4.5 CVT [1]

and with an unexperienced driver the gearbox can start alternating between the second and third gear if driven when under heavy load. The goal of the supplemental control algorithm is to prevent these gear alternations.

[1]The ECCOM gearbox series is a continuously variable transmission suitable for use within in agriculture e.g. tractors.

Background

Vehicle controller units

In the vehicle three mayor control systems exists. These systems interpret the inputs from the driver and controls the output so that the vehicle behaves in a way that the driver expects.

VDC is the vehicle driver control unit. It gives commands to the other control units and makes sure that the input from the driver is obeyed.

ECU is the engine control unit. It takes the motor reference and gives the appropriate control signal to the motor.

TCU is the transmission control unit. It makes sure that the gearbox obtains the desired gear ratio.

MicroAutoBox II - MAB

The MAB is a programmable box that can be connected to the vehicle control system. Through this box a possible modification of the current drive line strategy is possible. When a possible solution was to be tested it first got programmed to the MAB whereupon it was connected to the vehicle. An overview of the interaction and connections in the vehicle can be seen in figure 2.

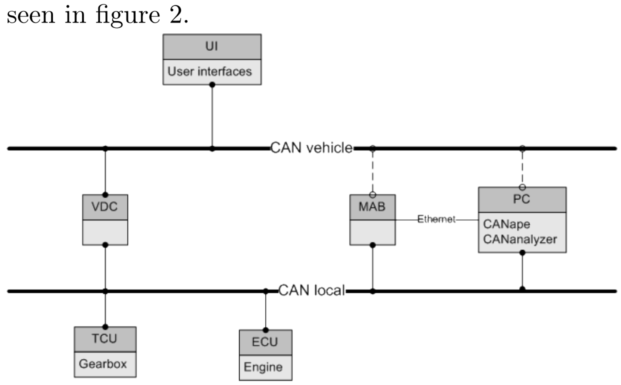

Figure 2: CAN-bus overview

Droop limit

In agriculture vehicles it is quite usual to have a droop limit. This limit is set by the driver and keeps the

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engine rpm from dropping below that preset value. During heavy load an engine usually starts loosing speed, when this happens and the droop limit is reached the gearbox starts gearing down so that the vehicle may cooperate with the heavy load without the engine dropping any lower. The advantages that comes with this is that the rpm can be kept at an optimum value. This can e.g. be from the fuel efficiency perspective or a maximum torque output perspective.

Tried solutions

The gear alternation problems occur if the load of the vehicle and the droop limit are badly combined. One solution to fix this problem is to alter the droop limit set by the driver. Different approaches to alter the droop limit has been developed. When the droop limit is altered in a positive way the gear ratio is pushed below the switching point, if the droop limit is lowered the gear ratio is increased. The effect of a 3% decrease of the droop limit in the simulink simulation can be viewed in figure 3. Unfortunately these

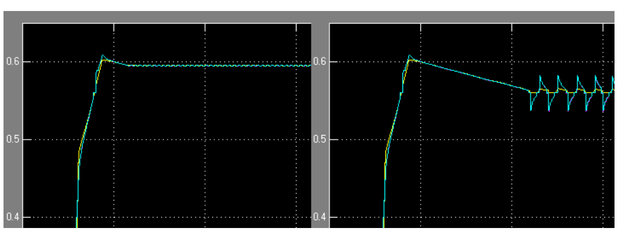

Figure 3: Controlled system vs. non controlled system.

beautiful results were not obtained on the real tractor instead a new problem unfolded. The problem was that depending on the current load a choice to push the droop limit in a positive or negative direction had to be made. Since load estimation is rather hard, an approach to lock the gearbox when gear alternation was a possibility was used instead. This approach locks the gearbox below the gear shifting point if some identified criteria are for filed. The criteria were that the engine should be under load, the gear ratio should be close to the switching point and if the ratio is rapidly changing nothing should be done either.

Result

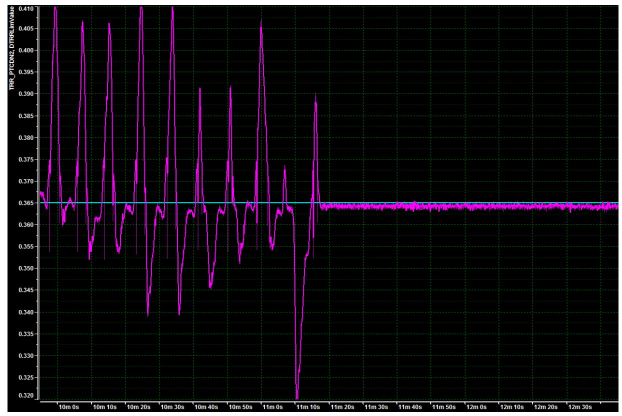

Figure 4: The affect of the gearbox lock on the gear ratio. The gearbox is set to be locked half way in the graph.

The results from the gearbox lock can be seen in figure 4. It can there be seen that the gear alternation is successfully suppressed when the gearbox lock is activated half through the graph.

Conclusion

From the results of the gearbox lock, seen in figure 4, the conclusion that this approach has got great potential is drawn. With some parameter tweaking for the criteria that should be for filed this could solve the gear alternation problem. The other approach of droop limit adjustment could also be used if a good way of load estimation could be implemented. If a good estimation of the load is implemented in the vehicle a higher level of controller is also possible in the form of optimal controllers. The optimal controller could optimize the the engine speed and the gear ratio to the current load.

References

[1] ZF Group. *Eccom 4.5* http://www.zf.com/corporate/en/press/media_service/press_kits/agritechnica_2009/Agritechnica_2009_Pressemappe.html, 2013-01-23.

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