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Automatic Braking of Agricultural Tractors

Functional Principles Involved in Applying the Service Brakes

The goal of this research project is to develop a deceleration management system for agricultural tractor-trailer combinations, which in the push mode automatically applies the tractor's service brakes in critical driving situations. In the first part of this article the problem, as well as the project goals and the approach chosen, were described [1]. Furthermore, basic strategies for detecting critical driving situations were illustrated. This article describes the functional principles involved in applying the service brakes in these situations.

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Keywords

Tractors, driving safety, deceleration management

Overspeeds of diesel engines can damage the inlet and outlet valves. At high speeds the valves might not be retracted fast enough by the valve springs and thus collide with the piston. If the tractor is equipped with a hydrostatic-mechanical power-split transmission, the CVT's axial piston pump and motor can also be damaged, because they are more sensitive to overspeeds than mechanical transmissions.

Engine speed thresholds

The controller for avoiding overspeeds was developed by using a numerical simulation of the system tractor-trailer-road. Previous to the development of the controller, two engine speed thresholds had to be defined. The thresholds determine the speed range in which the controller is working (*Fig. 1*). The upper threshold is the speed which the diesel engine must not exceed. It is determined by the design of the engine and has to be given by the manufacturers of the engine and of the transmission. The upper threshold was set to 2600 min^{-1} in the simulation. The lower threshold determines the activation speed of the controller. Speeds higher than these are considered overspeeds. The lower threshold should be chosen in such a way that the working range of the controller is large enough to allow a soft deceleration and thus not negatively affect the driving comfort.

The simulated diesel engine had a rated speed of 2200 min^{-1}. The lower threshold of the engine speed was set to 2300 min^{-1}. This provides a sufficient range between the rated speed and the lower threshold to prevent the controller from being activated at minor overspeeds. The controller's working range is 300 min^{-1} which should avoid an abrupt application of the service brakes.

The functional principle of the controller is shown in *Figure 2*. The controlled variable is the diesel engine speed, the manipulated variable is the vehicle's braking ratio. The closed loop controller is designed as a PI controller. This controller provides a fast response by means of the proportional element while the integrator keeps the control deviation low. The deviation is calculated by analysing the engine speed and its lower threshold. The engine speed and its set value are compared to detect whether the engine is in coasting mode or not. If the engine speed is

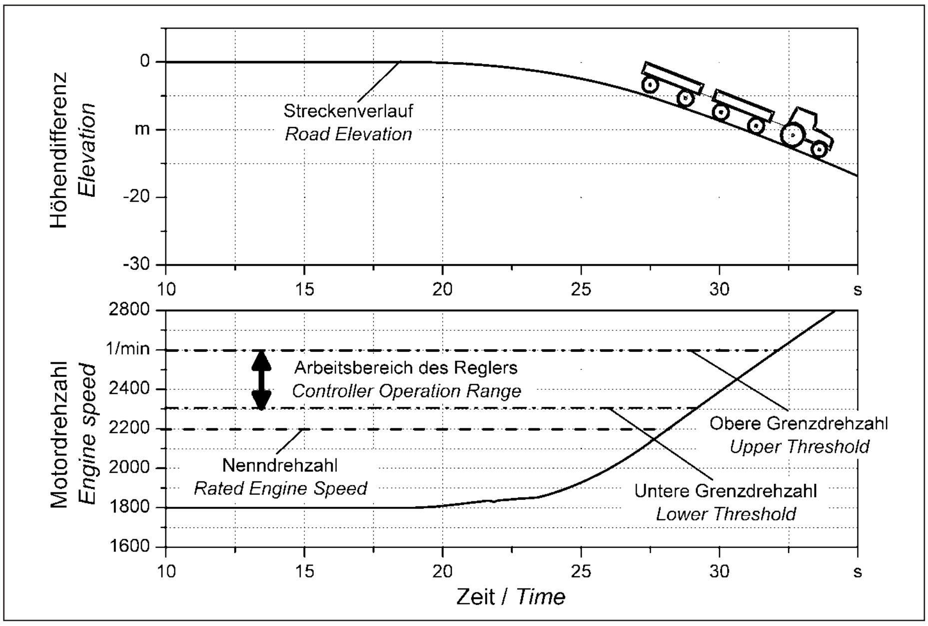

Fig. 1: Definition of engine speed thresholds

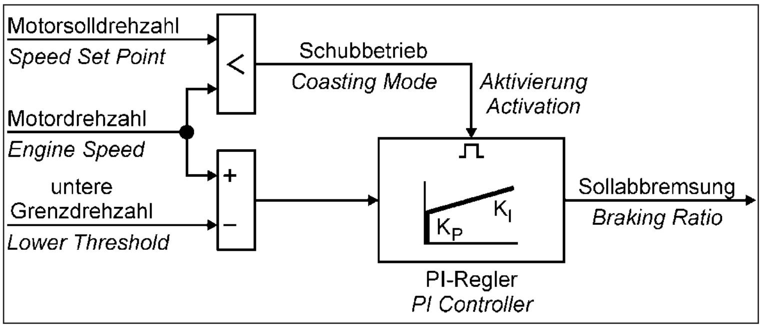

Fig. 2: Functional principle of the deceleration controller

larger than its set value, the vehicle is in coasting mode and the controller is activated. At engine speeds lower than the set value the controller is deactivated.

The controller worked well in the simulation. However, to keep the engine speed permanently lower than the lower threshold while driving downhill, the brakes had to be applied permanently. A permanent application of the service brakes, however, means a high thermal impact as well as mechanical wear of the service brakes. To avoid this, the braking controller should be designed to brake in intervals to allow cooling of the brakes between the braking cycles and minimize the mechanical wear.

The braking controller was modified accordingly. *Figure 3* shows two simulations of braking processes at different road slopes. After the engine speed exceeds its lower threshold, the threshold is lowered by following a ramp function. Thus, the engine speed is reduced to a value lower than the former threshold of 2300 min^{-1}. As soon as the lowered threshold has been under-run, the threshold is raised again to 2300 min^{-1}.

The value of the reduced lower engine speed threshold is determined during the braking process. The stronger the vehicle pushes in coasting mode, the further the threshold is reduced. This ensures that the service brakes get enough time to cool down even at steep slopes with a heavy vehicle. The vehicle's pushing load is determined during the braking process by analysing the maximum value of the braking ratio that is output by the controller. The higher the vehicle's load is, the higher is the braking ratio that is necessary to decelerate the vehicle. Thus, depending on the maximum value of the braking ratio, the lower threshold is decreased to a greater or lower extent.

Braking when the vehicle is unstable

A control system has been developed also for this driving situation. The goal is to apply the vehicle's service brakes when the slip of the driving axle is too high. This results in a braking of all of the vehicle's axles. Thus, to achieve the same braking ratio, the braking forces at each axle are substantially lower than before. This keeps the slip of all axles low and stabilises the vehicle. For details of this controller please refer to [2].

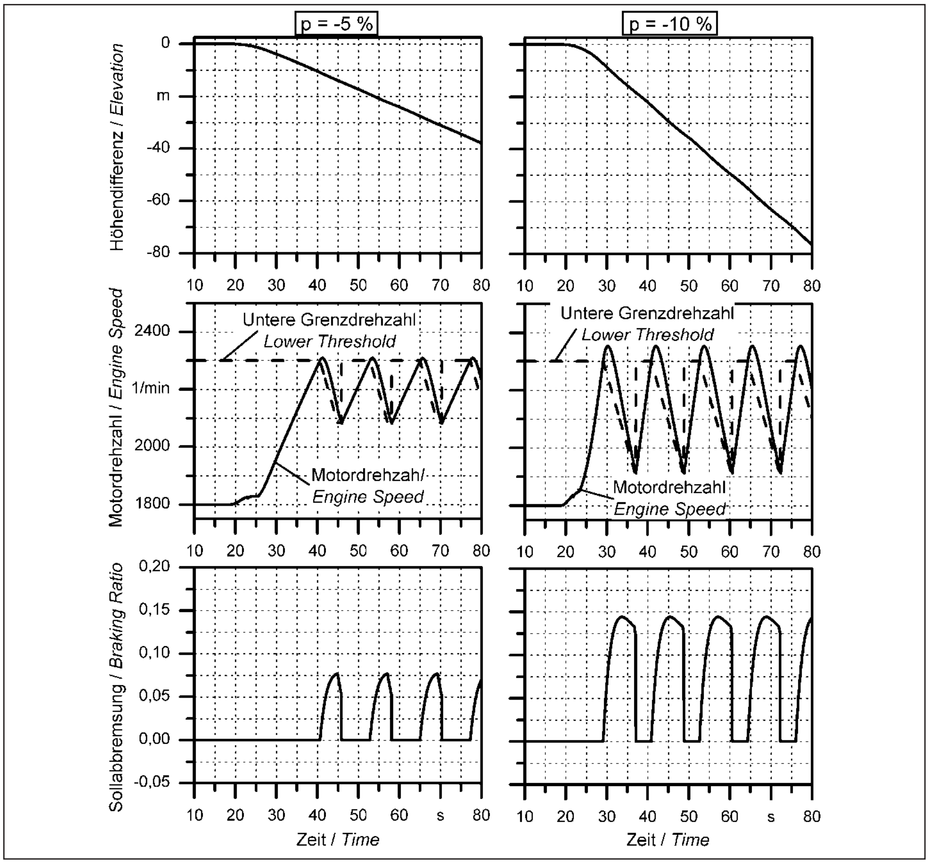

Fig. 3: Intervallic braking at different slopes

Summary

The goal of the research project was to develop the fundamentals of a deceleration management system for agricultural tractor-trailer combinations. The studies showed that the detection of the critical situations investigated can be accomplished by using sensors that are already present in state of the art tractors. During the project control principles were designed which allow a safe detection and a reliable prevention of critical situations.

Literature

Books are identified by •

[1] *Wiegandt, M. und H.-H. Harms*: Traktoren automatisch bremsen. Landtechnik 58 (2003), H. 4, S. 248-249

[2] • *Wiegandt, M.*: Grundlagen eines Traktorbremsmanagements. Dissertation, TU Braunschweig, 2004; Shaker Verlag, Aachen, 2004, ISBN 3-8322-3126-9