Validierung neuer Funktionen eines mechanischen Antriebsstrangs für mobile Arbeitsmaschinen mit radindividueller Steuerung

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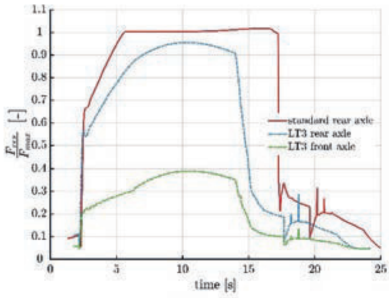
Abstract

In order to fulfil their vehicle process task, mobile machines are equipped with at least two drive trains to power the driving and working tasks. There are continuous efforts to optimize both drive trains. In terms of the traction drive, this means increased efficiency, improved traction and optimum adaptation to the vehicle task. This often leads to a conflict of objectives. A mechanical drive train enables high efficiency and the possibility of wheel speed compensation through differentials. However, it only provides poor traction, as only the torque of the wheel with the worst traction can be transmitted to all wheels. Therefore, modern machines can lock their differentials. This means that all wheels rotate at the same speed, which leads to tension in the drive train or forced slip on uneven ground or when cornering.

The LT3 powertrain is an approach to solve this conflict of objectives and meet the requirements mentioned above. It is a mechanical powertrain that could be propelled by any kind of engine or motor. The powertrain is similar to a conventional one, but there are no differentials, only fixed gears. Hence, it behaves like a locked powertrain transferring power mechanically by providing the maximum traction in any driving situation. However, with the differential being absent, the powertrain needs a new possibility to avoid slip and tension while realizing different wheel speeds when cornering. This managed by superposition gears in the lateral distribution of each driven wheel. To realize the capabilities of the differential, it is necessary to control the superposition of the speeds and torques for each wheel independently by means of a dedicated electrical control unit. Compared with conventional drivetrains, the strategy and behaviour of the powertrain are not determined by the design of the gears and differentials. The control of the powertrain is mainly determined by the ECU. This brings the possibility to implement different control strategies.

The basic function of the superposition gearbox of the LT3 system was successfully tested in a first project at the sub-system level according to VDI 2206. The next step is the validation as a complete system at the vehicle level. Therefore, the driving task was investigated by means of Mobile-Machinery-in-the-Loop (MOBiL), which is an X-in-the-Loop (XiL) method adopted to the needs of mobile machinery. The driving task can be divided into longitudinal, lateral and vertical dynamics. As far as the powertrain is concerned, the longitudinal dynamics are particularly relevant. For this reason, the previous investigations were aimed at evaluating the performance in traction mode. They show that the LT3 drivetrain provides equal traction force compared to a locked-differential drivetrain, while allowing individual wheel speeds during cornering.

In addition to traction mode, overrun mode must also be investigated. The aim of the current investigation in this field is the behaviour of tractor-trailer combinations in overrun mode. Many tractors are equipped with a continuously variable transmission. This enables the driver to easily adjust the vehicle speed. For convenience drivers brake the vehicle even via the drive lever. In general, this is not a problem, however, depending on the driving situation, it can become one. If, for example, the tractor pulls one or more heavy trailers at higher speeds up to 60 km/h, a critical driving situation can arise when decelerating via the drive train. The step less increase of the transmission ratio quickly leads to high braking torques on the powered axle. The moments can become so high that the tyres reach their traction limit and block the axle. In the case of the tractor, this is the rear axle that is relevant for driving stability. This causes the vehicle to skid and the trailer to buckle. The problem is exacerbated by increasing vehicle speeds and trailer masses. Road conditions also play a major role, so accidents can quickly occur on wet roads or when driving over grit.



$F_{Res} = \sqrt{F_X^2 + F_Y^2}$ $F_{max} = \mu_{max} * F_Z$

Fig. 1: Forces at the wheel contact point for one wheel

Fig. 2: Behaviour conventional tractor (purple) vs. LT3 tractor (green)

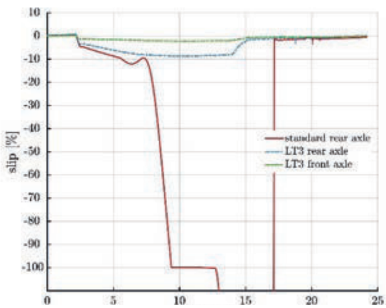


Fig. 3: Longitudinal wheel slip

Countermeasures that are in use today are limiting the speed at which the transmission ratio can be adjusted or setting a limit above a certain engine speed. This limits the maximum achievable drag torque of the motor and thus also the deceleration torque on the axle. Switching on the all-wheel drive is also a conceivable solution, but in the current technical implementation it is not possible at higher speeds due to clutches. However, if you consider a single-wheel drive such as the LT3 drive or other individually adjustable drive trains, this is possible. The continuous adjustable torque distribution allows torque to be distributed dynamically between the front and rear axles while driving. In conjunction with a slip-based control system, this prevents overloading of the powered rear axle. When the rear axle reaches its traction limit, torque is shifted to the front axle, thus relieving the rear axle. To validate this approach, a full vehicle simulation was set up. Braking manoeuvres were simulated on a straight road and during cornering, varying parameters such as vehicle speed, coefficient of friction and trailer mass. The simulation results show, that driving stability can be maintained even when decelerating via the drive train on poor ground. The use of a variable longitudinal torque distribution allows an increase in driving safety. The next step is to investigate the LT3 drive in terms of lateral dynamics. Improvements in lane change or evasive manoeuvres are conceivable.