Traction Control System (TCS)

Critical driving situations can occur not only while braking, but also whenever strong longitudinal forces should be transferred at the contact area between the tire and the ground. This is because the transferable lateral forces are reduced by this process. Critical situations can also occur when starting off and accelerating, particularly on a slippery road surface, on hills, and when cornering. These kinds of situations can overtax the driver not only causing him/her to react incorrectly but also causing the vehicle to become unstable. The traction control system (TCS) solves these problems, providing the vehicle remains within the physical limits.

Tasks

The antilock braking system (ABS) prevents the wheels from locking up when the brakes are applied by lowering the wheel brake pressures. The traction control system (TCS) prevents the wheels from spinning by reducing the drive torque at each driven wheel. TCS therefore provides a logical extension of ABS during acceleration.

In addition to this safety-relevant task of ensuring the stability and steerability of the vehicle when accelerating, TCS also improves the traction of the vehicle by regulating the optimum slip (see $\mu$-slip curve in “Basic principles of vehicle dynamics”). The upper limit here is, of course, set by the traction requirement stipulated by the driver.

Function description

Unless otherwise stated, all the following descriptions refer to single-axle driven vehicles (Fig. 1). It makes no difference whether the vehicle is rear-wheel or front-wheel drive.

Drive slip and what causes it

If the driver presses the accelerator when the clutch is engaged, the engine torque will rise. The drive axle torque $M_{Kar}$ also increases. This torque is distributed to both driven wheels in a ratio of 50:50 via the transversal differential (Fig. 1). If this increased torque can be transferred completely to the road surface, the vehicle will accelerate unhindered. However, if the drive torque $M_{Kar}/2$ at one driven wheel exceeds the maximum drive torque that can be transferred, the wheel will spin. The transferable motive force is therefore reduced and the vehicle becomes unstable due to the loss of lateral stability.
The TCS regulates the slip of the driven wheels as quickly as possible to the optimum level. To do this the system first determines a reference value for the slip. This value depends on a number of factors which are intended to represent the current driving situation as closely as possible. These factors include:

- the basic characteristic for TCS reference slip (based on the slip requirement of a tire during acceleration),
- effective coefficient of friction,
- external tractive resistance (deep snow, rough road, etc.),
- yaw velocity, lateral acceleration, and steering angle of the vehicle.

**TCS interventions**

The measured wheel speeds and the respective drive slip can be influenced by changing the torque balance $M_{\text{Ges}}$ at each driven wheel. The torque balance $M_{\text{Ges}}$ at each wheel results from the drive torque $M_{\text{Kar}}/2$ at this wheel, the respective braking torque $M_{\text{Br}}$ and the road torque $M_{\text{Str}}$ (Fig. 1).

$$M_{\text{Ges}} = M_{\text{Kar}}/2 + M_{\text{Br}} + M_{\text{Str}}$$

$M_{\text{Br}}$ and $M_{\text{Str}}$ are negative here.

This balance can obviously by influenced by the drive torque $M_{\text{Kar}}$ provided by the engine as well as by the braking torque $M_{\text{Br}}$. Both these parameters are therefore correcting variables of the TCS which can be used to regulate the slip at each wheel to the reference slip level.

In gasoline-engine vehicles, the drive torque $M_{\text{Kar}}$ can be controlled using the following engine interventions:

- Throttle valve (throttle valve adjustment),
- Ignition system (ignition-timing advance),
- Fuel-injection system (phasing out individual injection pulses).

The last two interventions are rapid interventions, the first a slower means of intervention (Fig. 2). The availability of these interventions depends on the vehicle manufacturer and engine version.

In diesel-engine vehicles, the drive torque $M_{\text{Kar}}$ is influenced by the electronic diesel control system (EDC) (reduction of the quantity of fuel injected).

The braking torque $M_{\text{Br}}$ can be regulated for each wheel via the braking system. The TCS function requires the original ABS hydraulic system to be expanded because of the need for active pressure build-up (see also “Hydraulic modulator”).

Fig. 2 compares the response times with various TCS interventions. The figure shows that exclusive drive torque regulation by means of the throttle valve can be unsatisfactory due to the relatively long response time.