

# VIA VISION

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Editorial – Dr. Ulrich Hackenberg

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# Brakes

## The Art of Slowing Down

**0.3 seconds**

is the reaction time a car driver needs  
before applying the brakes – at least.

**100 percent**

of all new cars in Germany  
are equipped with ABS.



## Editorial



Dr. Ulrich Hackenberg,  
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A car without brakes is just as unthinkable as a car without an engine. In this issue, VIAVISION explains how brakes work, which properties the materials used have to possess – and even how energy can be won through deceleration.

I wish all readers a happy read.

# Under Pressure

## From Pedal Pushing to Standstill

The braking process of a bicycle is easy to see: a steel cable is pulled, via a handbrake, pushing rubber blocks against the wheel to its left and right. The principle is similar for the car, except that here brake pads and steel brake discs or drums are employed. Instead of the steel cord a hydraulic fluid, which circulates in a closed brake circuit, provides the necessary pressure. Because braking is one of the most important safety functions, every car has a second brake circuit, so that at all times at least two wheels are capable of braking. Braking power is strongest at the front wheels, because during braking the weight of the car shifts to the front.

**18** kilometres per hour is the minimum speed reduction a car braking system must achieve per second.

Source: Straßenverkehrs-Zulassungs-Ordnung (as of 2012)

**0.3** seconds is the reaction time a car driver needs before applying the brakes – at least.

Source: Konrad Reif, „Bremsen und Bremsregelsysteme“ (as of 2010)

### Stopping distance: (in metres)



Dry road surface



Rain-slicked road surface



Snow-covered road surface

*The surface is what matters: if the road is wet or snowy, the braking distance, at a given speed, is extended. On snowy roads, it is even twice as long as on dry tarmac. The reason: the tyres' grip on the road, which brakes the car, is lower when a layer of water or snow is in between. Also heavy load, high speed and poor tyre condition lead to an increased braking distance.*

Sources: University of Innsbruck, Department of Mathematics (as of 2012); Konrad Reif, „Bremsen und Bremsregelsysteme“ (as of 2010)

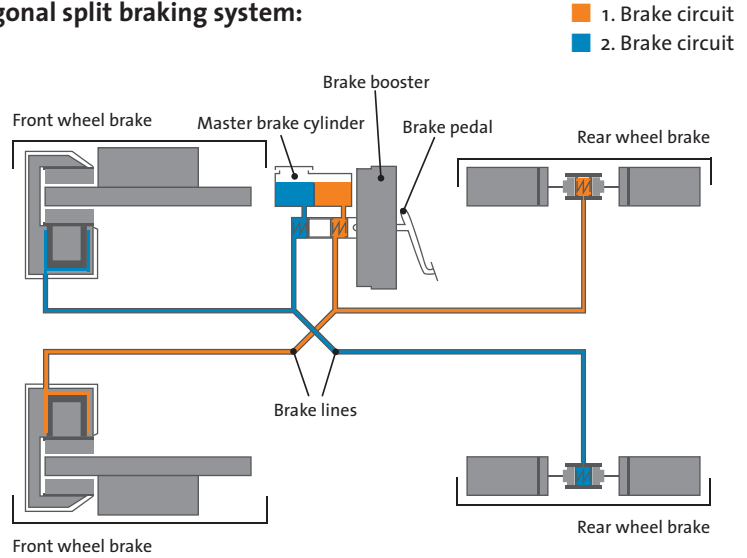
\*At a speed of 120 kilometres per hour.

**Braking sequence**

The braking process begins with the driver stepping on the brake pedal. The strength of the pressure regulates how much brake fluid from the master brake cylinder is pushed into the brake lines. This pressure is increased using the brake booster: in most car braking systems this happens via negative pressure in the chambers of the brake booster, so that a higher pressure acts on the main cylinder than that applied by foot alone. It is legally mandatory that vehicles are equipped with two brake circuits, in case one of the brake circuits fails.

Sources: Konrad Reif, „Bremsen und Bremsregelsysteme“ (as of 2010); Straßenverkehrs-Zulassungs-Ordnung (as of 2012)

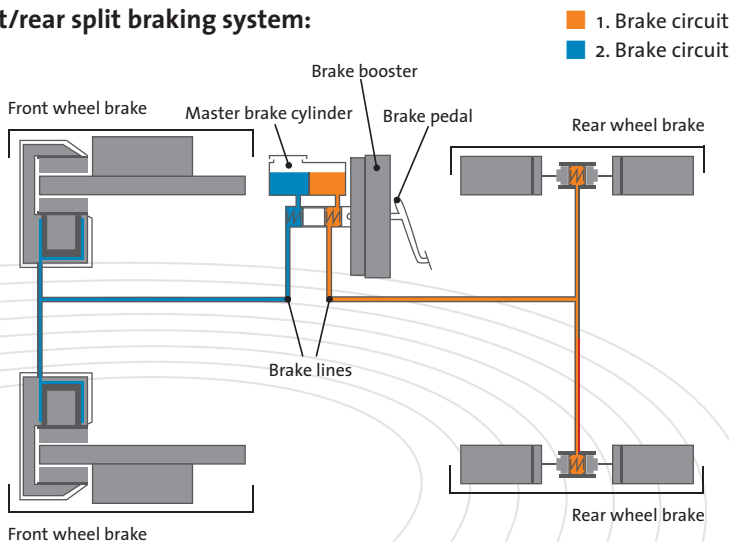
**Diagonal split braking system:**



*In a diagonal brake circuit the two diagonally opposite wheels are decelerated. The advantage: that both brake circuits are equivalent. However, the cross-braking effect leads to larger yawing moments. This means the car can swing laterally and is harder to keep on track.*

Source: Continental (as of 2012)

**Front/rear split braking system:**



*In a brake system with a front/rear split both front wheels and rear wheels belong to a separate brake circuit, respectively. With this division there are only slight yawing moments – the vehicle can more easily be kept stable. The disadvantage: a failure of the front brake circuit decreases the braking power more severely.*

Source: Continental (as of 2012)



**Negative acceleration**

In physical terms braking is a type of acceleration – namely negative acceleration. Background: acceleration is a change in speed per unit of time, regardless of whether the vehicle speeds up or slows down. If the driver puts his foot down, he accelerates, for example, by +20 kilometres per hour. If he steps on the brake, he accelerates by –20 kilometres per hour.

Source: Technical University Dresden, Institute of Theoretical Physics (as of 2011)

## Parking brake

The parking brake ensures that the parked vehicle does not roll away. In most cases it is a handbrake but there are parking brakes which are operated by foot or by pressing a button. According to an EC Directive, the parking brake must be able to, purely mechanically, keep a loaded vehicle static on an 18 percent uphill or downhill gradient. It must function independently from the service brake system but it may employ its components – for example, the drum brakes on the rear wheels – at the same time.

Sources: European Commission, Directive 98/12/EG (as of 2001); Konrad Reif, „Bremsen und Bremsregelsysteme“ (as of 2010)

## Electric handbrake

The driver activates the handbrake with a button, the brake pads are then electrically clamped onto the rear brake discs; they are released automatically at the start. The system is used in the Volkswagen Golf, Tiguan, Passat and Touareg models.

Source: Volkswagen

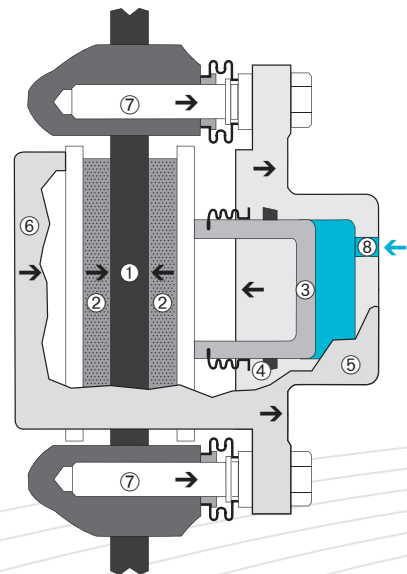
# Gripping

## Brakes Do the Hard Work

The brakes must be able to take back the kinetic energy generated by the engine. The performance of the four wheel brakes must therefore be at least as large as that of the motor. The hydraulic pressure that is generated by using a liquid ultimately acts on the brake pads, bringing the car to a halt by creating friction against a brake disc or drum. In new vehicles disc brakes are exclusively installed in the front and the rear wheels are sometimes equipped with drum brakes. The advantage of disc brakes: they are surrounded by air stream and cannot overheat so easily.

### The disc brake: (example sliding calliper brake)

- ① Brake disc
- ② Brake pad
- ③ Piston
- ④ Piston sealing ring
- ⑤ Casing cover
- ⑥ Casing bottom
- ⑦ Guiding bolt
- ⑧ Connection from master cylinder



*The sliding calliper disc brake design decelerates the car by pressing two brake pads to the left and right of a brake disc. It is connected to the wheel and rotates with it. When the driver steps on the brake pedal, the fluid from the master cylinder is pressed through the brake lines and hoses (see page 3) into the cylinder of the disk brake. Its piston then pushes on one side against the brake pad which then pushes against the brake disc. The other brake pad is pressed against the disc by the piston which moves against the sliding lid, so that the housing bottom slides on the guide bolts together with the brake pads in the direction of the brake disc. Most cars are equipped with the space-saving sliding calliper brake. Besides this there is the similarly constructed floating calliper brake and the fixed calliper brake, on which brake cylinders lie on both sides of the brake pads.*

Sources: Konrad Reif, „Bremsen und Bremsregelsysteme“ (as of 2010); Karlsruhe Institute of Technology, Institut für Fahrzeugsystemtechnik (as of 2012)

# Heat Resistant Special Materials for Brakes

Independent of the road surface and vehicle weight, all braking processes have one thing in common: they produce heat. The resulting temperatures can be several hundred degrees Celsius. Discs, pads and fluids – the components of the braking system – must be reliable and work permanently, even under these extreme conditions.

**3.5** millimetres is how thick a brake lining must be at least, otherwise it must be replaced.

Source: Konrad Reif, „Bremsen und Bremsregelsysteme“ (as of 2010)

**2** years old is the maximum age for the brake fluid in a car. After that it might have absorbed sufficient water to boil when braking.

Source: Konrad Reif, „Bremsen und Bremsregelsysteme“ (as of 2010)



Picture: Frettie

## Brake fluid

**Requirements:** The brake fluid should, above all, not do one thing: form bubbles. Upon compression of fluids any of the bubbles burst first, only then does compression pressure build up. This means the pressure on the brake pedal, which compresses the liquid in the brake lines so far that the hydraulic pressure induces the braking process, would have to be much longer to bring the car to a halt.

**Material:** For the brake fluids, fluids with a boiling point of over 230 degrees Celsius, and which can absorb infiltrating water, are used exclusively. Glycol based fluids are common.

Sources: Konrad Reif, „Bremsen und Bremsregelsysteme“ (as of 2010); ADAC; United States Department of Transportation (both as of 2012)



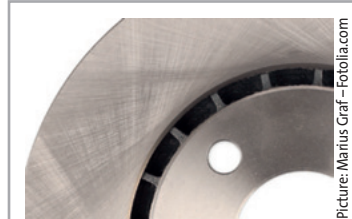
Picture: gourmecana – Fotolia.com

## Brake lining

**Requirements:** The actual braking takes place between the brake lining and brake disc. The material of the lining must therefore be such that sufficient mechanical friction is generated with the brake disc, but it is not inflamed by the resulting temperatures and that it will not wear too much due to friction.

**Material:** Brake pads are made of metals such as steel wool, fillers such as alumina, lubricants such as graphite and organic components like binder resin. The exact composition varies depending on the manufacturer.

Sources: ADAC (as of 2012); Konrad Reif, „Bremsen und Bremsregelsysteme“ (as of 2010), Economic Commission for Europe ECE (as of 1999)



Picture: Manius Graf – Fotolia.com

## Brake disc

**Requirements:** Between brake disc and pad arise temperatures of up to 500 degrees Celsius when braking. The material used for the discs must be heat resistant, meaning that it does not change shape when exposed to heat.

**Material:** Normally brake discs are made of cast iron or steel. Very fast vehicles can also be equipped with composites such as carbon fibre (carbon fibre reinforced plastic) or carbon-ceramic which weigh considerably less and can withstand temperatures of 1,000 degrees Celsius.

Sources: ADAC; SGL CARBON (both as of 2012)

# Fast Helper

## Braking Assistants Ensure Safety

### Electronic differential lock XDS

Technically speaking, XDS is an added feature of the ESP-integrated electronic differential lock (EDL). As soon as the electronics recognise that the inside front wheel is facing a loss of traction due to a strong load relieve, brake pressure is increased specifically at this wheel, thereby ensuring sufficient contact with the road.

Source: Volkswagen

### Multi collision brake

If the air bag sensors register a collision, the multi collision brake automatically kicks into action and slows the vehicle down to a rest speed of 10 kilometres per hour. This prevents the vehicle from keeping rolling uncontrollably. The control system is only switched off again when the driver noticeably presses the accelerator pedal, or initiates braking. A multi collision brake is fitted as standard in the new Golf.

Source: Volkswagen

People make mistakes. This may have disastrous consequences, especially on the roads. At the interface between man and machine braking assistants ensure that the braking process begins earlier, is more secure and works as strongly or weakly as necessary. They can also take on other tasks: they scan the environment with sensors, help to keep a spinning vehicle under control, draw the attention of the driver to hazards and can even trigger an emergency stop.

**88** percent of all cars in Germany were equipped with ABS in 2011. The rate in new cars was 100 percent. Source: DAT Report 2012

### Anti-lock braking system (ABS)

In the past so-called cadence braking was taught in driving schools. This refers to the repeated release of the brake pedal during the braking process: so the wheels do not lock up and the car remains steerable. This is exactly what the ABS does in newer generation vehicles: wheel sensors continuously monitor the speed of all wheels. Based on this data a so-called hydraulic modulator is switched on, if necessary, which reduces brake pressure on each wheel using magnetic valves so that it moves freely and remains steerable.

Sources: University of Münster, Institut für Informatik (as of 2005); Bosch (as of 2012)



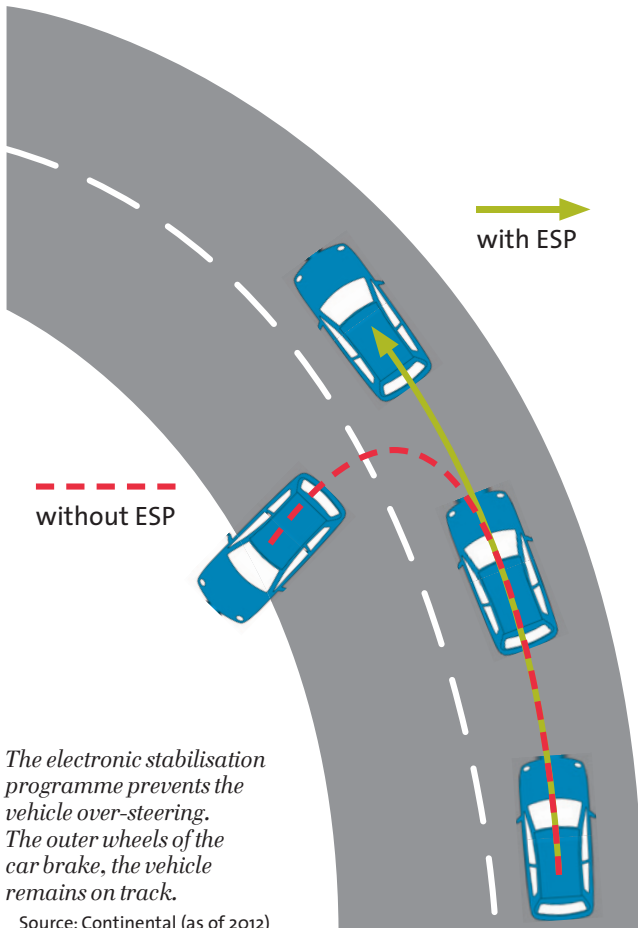
### Brake assist

In emergency braking situations, drivers often brake insufficiently hard or take the pressure off the brake pedal too quickly. At this point the brake assist function is triggered: as soon as the system detects that the driver prompted an emergency brake, it amplifies the braking process until the maximum braking pressure is reached. The brake assist brakes until the driver releases the pedal. Whether it really is an instance of an emergency stop, the brake assist system detects by the initial pedal movement or the brake pressure. The brake assist shortens emergency braking from 100 kilometres per hour by up to 20 percent.

Sources: Hermann Winner et al., „Handbuch Fahrerassistenzsysteme“ (as of 2012); German Association of the Automotive Industry (VDA), Annual Report 2012



ESP in action:



The electronic stabilisation programme prevents the vehicle over-steering. The outer wheels of the car brake, the vehicle remains on track.

Source: Continental (as of 2012)

**Electronic stabilisation programme (ESP)**

ESP is essentially an extension of the anti-lock braking system. While ABS intervenes only when braking, ESP can also decelerate individual wheels when rolling or accelerating, to prevent the vehicle skidding. Moreover, ESP can actively engage in the steering process, and change the steering angle. This requires a large number of sensors: wheel sensors monitor the speed of the wheels; a steering angle sensor signals to the on-board computer where the driver is steering; the yaw rate sensor detects the rotational movements of the vehicle to the left and right; another sensor detects the lateral acceleration of the vehicle, if for example the car slides sideways on slippery surfaces. All the collected data is transferred to a controlling device that can control each wheel individually, independent of the pressure on the brake pedal.

Source: ADAC (as of 2011)



**2014** is the year in which all new cars in the EU have to be equipped with ESP.

Source: German Association of the Automotive Industry (VDA), Annual Report 2012

**City emergency brake**

Depending on the model, a laser or radar sensor scans an area of about ten metres ahead of the vehicle. Upon an impending collision, without the driver responding, the brake system builds up so much pressure that the brakes respond immediately if the driver presses the brake pedal. When the driver steps off the gas, the system is already autonomously braking. If he only presses the brakes weakly, the activation of the brake assist guarantees full deceleration. Ideally this avoids rear-end collisions entirely. City emergency braking is one of the emergency brake assistance systems that are put to use in the Volkswagen up!, Golf and Passat models.

Sources: German Association of the Automotive Industry (VDA), Annual Report 2012

# Recovery


## Harnessing Braking Energy

Brake and save fuel? This is possible. To put the car in motion, fuel must be expended which is converted into kinetic energy in the engine. During braking, the energy is converted into heat that is normally lost to the environment. In order to re-use at least a part of it, manufacturers make use of recuperation. The term originates from Latin and means recovery.

### Internal combustion engine

In a conventional internal combustion engine the alternator, as a generator, generates electric energy with which the car battery is then charged. That costs extra fuel, specifically about 0.1 litres per 100 watts of power. This process is known as recuperative if it occurs during braking or the use of the engine brake – thus in this way saving fuel.

Sources: ADAC Technology Centre (as of 2012); HELLA (as of 2011)


 **10%** of fuel at most can be saved by recuperation in an internal combustion engine.

Source: University of Paderborn, Power Electronics and Electrical Drives (as of 2011)

### Electric car

In hybrid or electric vehicles the electrodynamic brake ensures energy recovery: the electric motor is switched to generating electricity by stepping on the brake pedal, it then turns harder and slows down the vehicle even before the mechanical brakes are used at all. Thereby electric power is generated, which is fed into the battery of the vehicle and used again, for example when starting up, the operation with the highest energy consumption.

Sources: ADAC Technology Centre (as of 2012); HELLA (as of 2011)

 **20%** percent of fuel and electricity, at most, can be saved in hybrid cars via recuperation.

Source: ADAC Technology Centre (as of 2012)

## Imprint

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