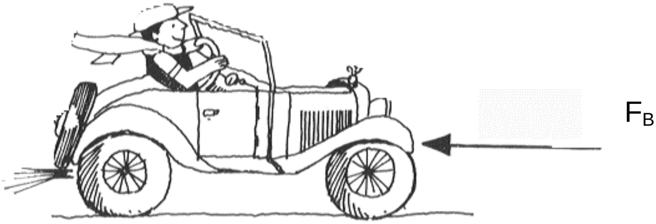
Brake Booklet

1 What is braking

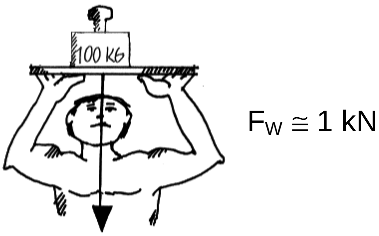
1.1 The braking force F_B:



The braking force F_B is necessary in order to brake vehicles from a high speed down to a low speed; it always acts in the opposite direction of the movement.

1.2 The unit for braking force

Force is measured using the unit N (named after the English physicist, Isaac Newton).



- F = 1000 N = 1 kN

corresponds approximately to the force F_W due to weight of 100 kg, which amounts exactly to 0.981 kN.

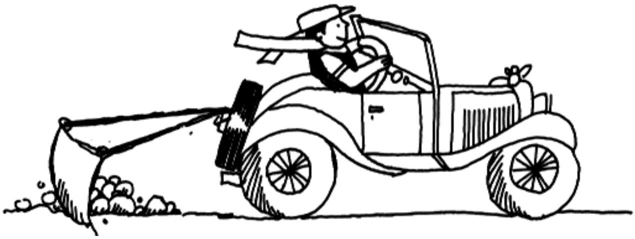
1.3 Various braking possibilities

There are many ways of applying the brakes on a car; the following sketches show a few of them:

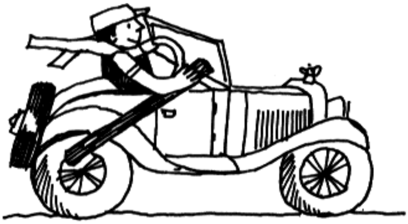
I painful and disastrous

II little braking action

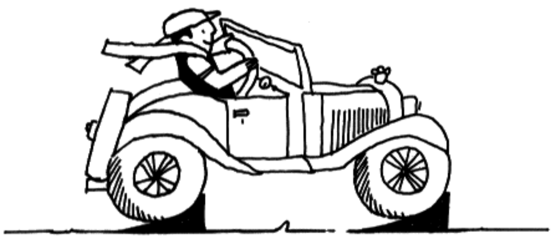
III ruthless road treatment



IV



V



Cases IV and V show the right way: Applying the brakes to the wheels.

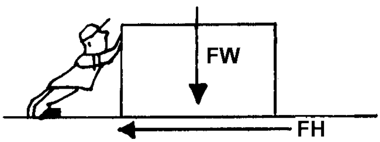
2 How is braking performed?

2.1 Physics

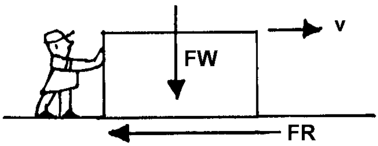
A few fundamental physical observations:

I Adhesive force (friction) F_H (adhesion)

Speed v = 0



II Frictional force F_R (Sliding)



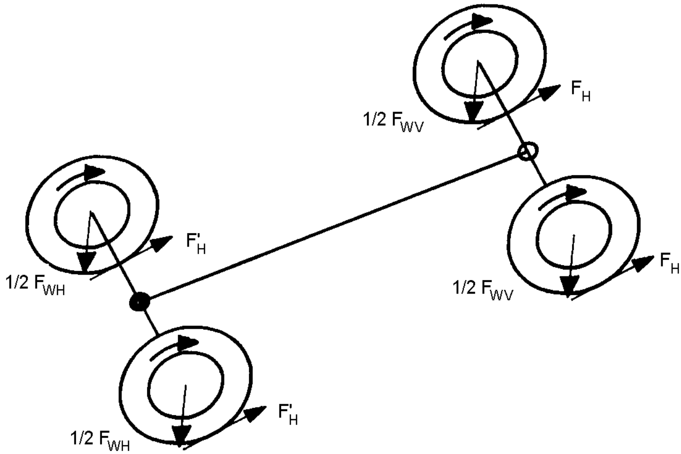
More force is necessary to start a stationary object into motion than to keep it in continuous motion.

Adhesive and Frictional forces are proportional to the force due to weight of the body and depends on the characteristics of the adhering and/or sliding material surfaces (e.g. unevenesses).

- $F_H = \mu_H \cdot F_W > F_R = \mu_R \cdot F_W$
  (μ_H: adhesive value, μ_R: frictional value)

2.2 Arising adhesive and/or frictional forces with a car

The sketch shows forward motion without braking force, F_{WH} is the rear axle load and F_{XV} is the front axle load.



The adhesive and frictional forces for each wheel depend, on one hand, on the respective acting fraction of force due to weight of the car on this wheel (in the simplest case, this is the axle weight divided by the number of wheels underneath the axle in question) and, on the other hand, on the respective adhesive and/or frictional value between the wheel and supporting plane.

Differing axle loads and differing wheel-support relationships result in differing adhesive and frictional forces.

2.3 Driving and braking

Good driving and braking forces are present when the driving and braking forces created within the car are optimally transferred onto the supporting plane - usually the road surface.

This ideally occurs when the wheel rolls with firm adhesion on the supporting plane and does not slide on it (slippage).

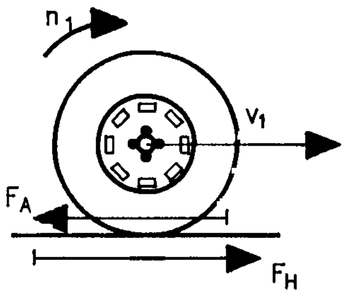
Sliding and/or slipping of a wheel always occurs when the driving and/or braking force, which is acting on this wheel, becomes larger than the adhesive force.

In the case of driving forward, the wheels spin - the dashing start; in the case of braking, the wheel more or less begins to slip on the supporting plane - it rotates less than it should for the corresponding braking distance.

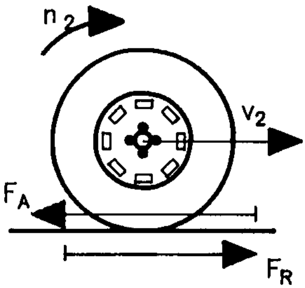
If the wheel locks up, now only the smaller frictional force is effective and the stronger gripping of the car brakes onto the wheel has no effect; in addition, the behavior of the car becomes uncontrollable.

I Driving (driving force F_A)

Rolling:



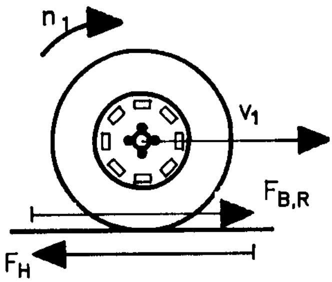
Slippage (partial sliding):



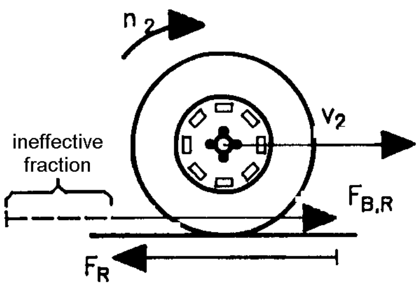
- n_1 smaller than n_2 and v_1 larger than V_2.

II Braking (wheel braking force $F_{B,R}$)

Rolling:



Slippage (partial sliding):



Remarks: The braking force $F_{B,R}$ on one wheel can never be larger than the adhesive force between the wheel and the supporting plane.

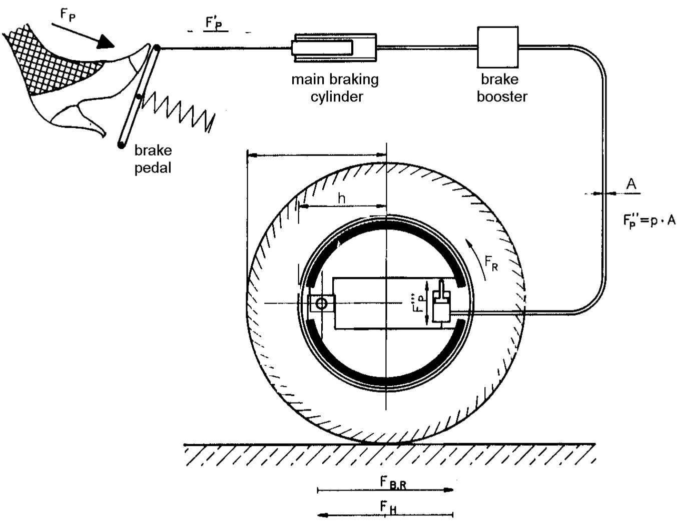
2.4 Creating braking force

The braking force $F_{B,R}$ on the wheel surfaces is released by pedal force F_P, created at the brake pedal, which is increased by means of levers and hydraulics and the transferred as compressive forces F_P^{III} to the brake discs (or drums). With this, frictional force F_R is created (at this point, there may not be any adhesion, since otherwise the wheel would lock).

The torque brought about by this in connection with the wheel axle ($M = F_R \cdot h$) is equal to the torque $M = F_{B,R} \cdot r$ (r = radius of the wheel) for a wheel which is rolling, not slipping.

Es gilt

- $F_{B,R} = F_R \cdot \frac{h}{r} = f \cdot F_P$ with f = transfer factor.

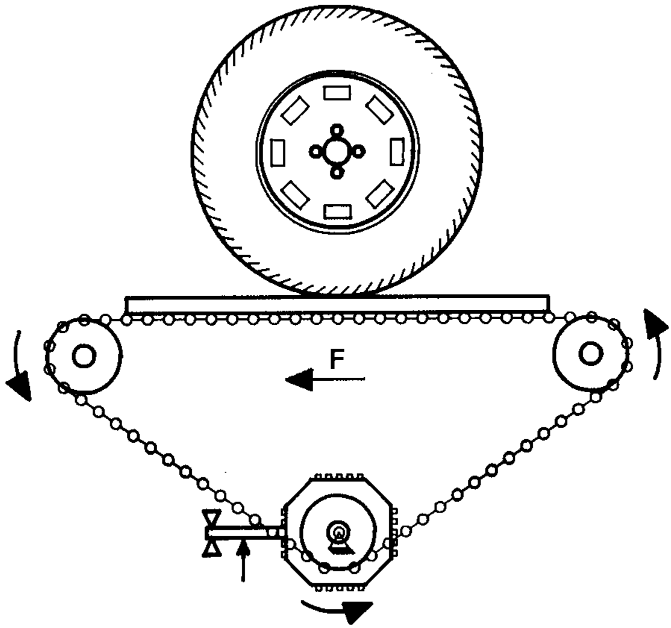


3 How are braking forces measured?

It is important that the respective braking forces of the wheels are the same for one axle in order to avoid skiding. Consequently, each wheel is measured for itself alone on a brake tester.

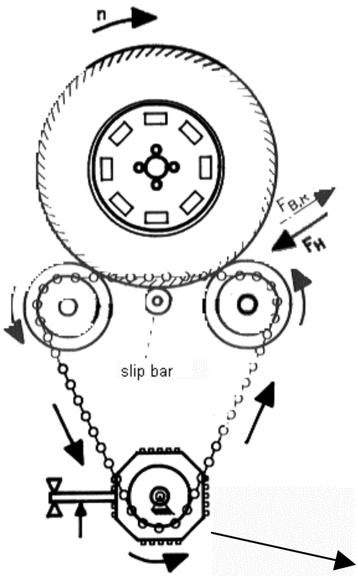
For this, a static and a dynamic method are available.

3.1 Static testing method



With the static method, the force is determined that is necessary to rotate a wheel, which is positioned in a stationary state on a plate, when the brakes are applied.

3.2 Dynamic testing method



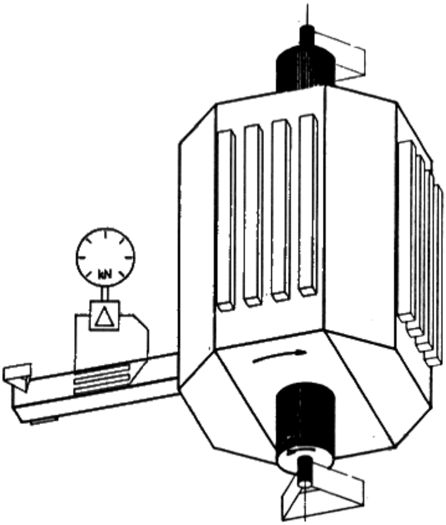
Rotary mounted drive motor with transverse beam supporting of the housing

With the dynamic method - practical experience-orientated - the wheel is brought up to a specified speed by the motor driven rollers and then the brakes are applied.

A slip bar directly measures the wheel revolutions. From the comparison of drive roller with the slip bar revolutions, the amount of slippage can be determined.

With a slippage of approx. 30 % or more, measuring of the braking force is no longer reasonable. The tire wear would then become too high. Thus the brake test is interrupted.

3.3 The measuring principle

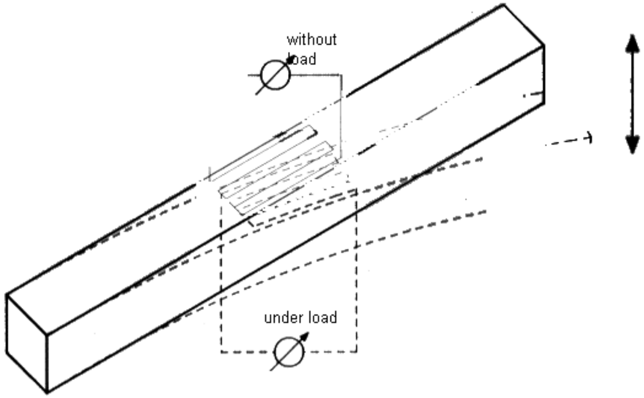


The measuring principle is the same for both methods of testing. The drive motor is supported in a rotary fashion; without any additional support, the drive shaft and the housing would counter-rotate when under load depending on the force distribution.

This additional support consists of a beam which the housing is placed on. The steel beam bends corresponding to the torque produced by the motor which the beam has to resist.

The torque is zero when beginning the static method of brake testing and, with the dynamic method, is just as high as necessary in order to bring the drive rollers and wheel in motion when the brakes are applied.

3.4 The measuring sensor



A wire strain gauge (DMS) is mounted on the transverse beam, whose high length-dependent electrical resistance is measured.

This is a very sensitive measuring gauge for the bending of the beam and thus also for the torque created at every phase of the braking test. This torque can be easily converted into the braking force between the wheel and the supporting plane and then displayed.

4 Brake Tester Measurement Results and Evaluations

4.1 Deceleration in general

The deceleration measurements how quickly the speed of a vehicle is reduced; in other words, how much the speed is reduced in what amount of time. The equation to show this is as follows:

- $a = \frac{v}{t}$ in m/s²

whereby v represents the speed change and t the time needed.

Example:
A vehicle goes from 20 m/s (= 72 km/h) to standstill in 5 seconds. The result is a deceleration of 4 m/s².

4.2 Deceleration Measurement on Roller Brake Testers

Many countries require that vehicles, depending on categories, reach a minimum deceleration. Generally speaking, deceleration measurements on the open road are too troublesome meaning that roller brake testers are commonly used.

If the minimum deceleration is not achieved, the vehicle may not be driven on the road.

The brake force and the weight of the wheels/axles (if equipped with scales) can be measured on the roller brake tester.

The vehicle deceleration can also be determined by using the maximum achieved brake force in relation to the weight. The equation for this is shown below:

- $a = \frac{FB}{G}$ in m/s²

Example:
The four wheels of the vehicle attain a total brake force of 8000 Newton during the brake test. The vehicle weight is 1600 kg. The result is a deceleration of 5 m/s².

The deceleration is often displayed as a percentage value of the acceleration due to gravity which is 9,81 m/s². The percentage deceleration is then 50,97 % for the example above.

4.3 Frictional Coefficient

The maximum attained brake force is directly dependent upon frictional coefficient µ between tires and surface as well as the force with which the wheel is pressed on the ground. (normal force) The following equation applies:

- $FB = \mu \cdot FN$

The following frictional coefficients are common for average tire rubber mixtures under natural conditions:

- Concrete dry: ~0.7
- Asphalt dry: ~0.6
- Snow: ~0.2
- Slippery ice wet: ~0.01 – 0.1

Generally speaking roller brake testers have surface structures which simulate concrete or asphalt frictional coefficients, i.e. reach approximately 0.7.

4.4 Brake force imbalance

When one of the brakes of an axle is less effective than the other, one-sided brake effectiveness occurs which is called brake imbalance or unequalness.

If the difference is too large, the vehicle tends to break away in the direction of the side which brakes heavier. For this reason, a vehicle is road unworthy once a certain limit value is exceeded.

In many countries the difference is shown as a percentage value of the measured brake force difference related to the higher of the two brake forces. This is usually calculated as follows:

- Difference (%) = $\frac{\text{FB (higher) - FB (lower)}}{\text{FB (higher)}}$

Example:
The left wheel has a brake force of 2 kN. At the same time 3 kN is measured on the right hand wheel. The difference is then 33 %.

Extreme fluctuations in the value may then occur because the difference is always determined from the currently valid brake forces. This may be the case if, for example, the brake drums (discs) show a heavy out-of-round. If a measured brake force of a wheel using a steady brake pedal position fluctuates between 2 kN and 3 kN due to out-of-round and the other wheel reaches a steady brake force of 2 kN, then the difference fluctuates between 0 % and 33 %. Attention should be paid to this kind of influence while measuring brake force differences otherwise it may lead to different results each time a measurement is repeated.

4.5 Out-of-Round (Ovality)

As described in point 4.4 brakes can be out-of-round. To measure the out-of-round, the pedal is held steady at the desired measurement point. Then the test stand display value should show a constant brake value. Out-of-round brakes however show a fluctuating display. The out-of-round is calculated then from the difference between the highest brake value and the lowest brake value during the out-of-round measurement.

Example:
The measurement value of a wheel brake fluctuates between 1.9 kN and 2.2 kN with a steady brake pedal position. The out-of-round is then 0.3 kN.

To determine a percentage out-of-round value the out-of-round is often in reference to the max. brake force value.

Example:
The above brake reaches a max. brake force value of 3 kN. The percentage out-of-round in this case is 10 %.

Depending on the statutory regulations, vehicles are considered road unworthy beyond a certain out-of-round value.

MAHA Maschinenbau Haldenwang GmbH & Co. KG.
D-87490 Haldenwang (Allgäu) · Hoyen 20
Fon +49 (0) 8374 / 585-0 · Fax +49 (0) 8374 / 585-499
Internet www.maha.de · E-Mail maha@maha.de

D1 0213FI1-GB02