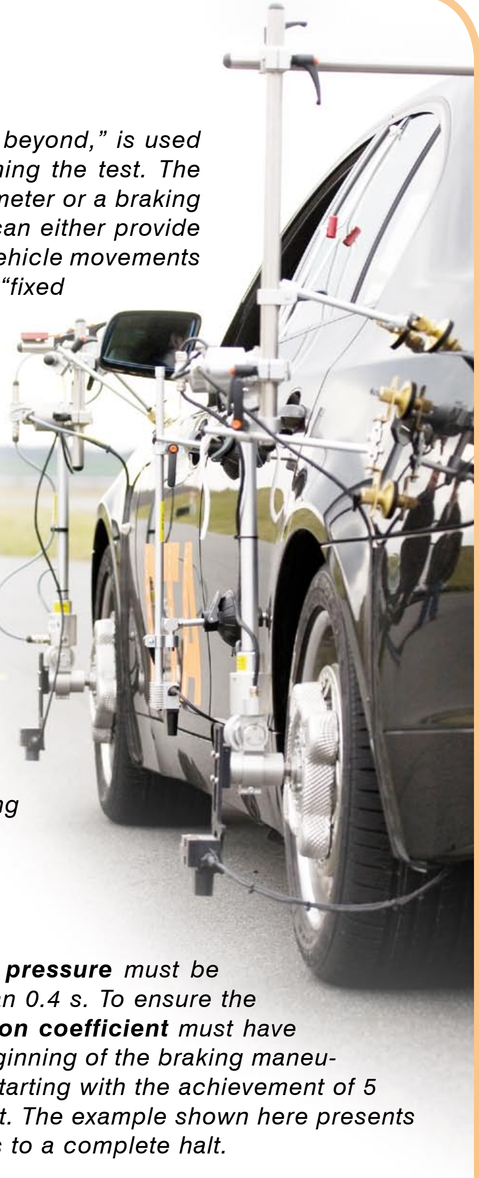
Fahrdynamik Test Allianz
DTA
Driveability Testing Alliance

Driveability Test Maneuver:

Straight-line Braking



Objective of the Driving Maneuver

*The vehicle dynamics test, “straight-line braking according to DIN 70028 and beyond,” is used to evaluate **actual braking deceleration** and **vehicle stability** while performing the test. The required brake pressure can either be adjusted by the driver using a decelerometer or a braking machine can assume this task in a way that is exactly repeatable. The driver can either provide **steering wheel inputs** for directional control (closed loop) or he registers the vehicle movements in the open-loop procedures of “free control“ (letting go the steering wheel) or “fixed control” (fixed holding of the steering wheel).*

*The objective of this vehicle dynamics test is to demonstrate a design of the **braking system** which is **suitable for the particular vehicle** by combining good levels of comfort (responsiveness, operating force, etc.) with the **shortest possible stopping distances**. This aspect is given above-average consideration in overall vehicle evaluations by auto magazine consumer tests, such as the ams (auto motor und sport) test in Germany. According to statutory requirements it must be assured that up to a **vehicle deceleration of 0.8 g** and above the front wheels always lock before the rear wheels because locking rear wheels result in the vehicle’s instability.*

*The **road conditions** for the tests should be standardized: dry or wet conditions or surfaces with a low friction coefficient. The longitudinal inclination of the road should be* ≤ 1 % *and* ≤ 0.2 % *in the transverse direction. The adhesion coefficient of the tires/road should be* $\mu \geq 0.9$. *Especially for ABS developments, vehicle stability is evaluated with different friction coefficients of the driving lanes on the vehicle sides (*μ_{split}*) or in case of changes of the road friction coefficient in transverse direction to the direction of travel (*μ_{jump}*). The braking system must be iteratively designed for optimum use of road/tire adhesion.*

Test Procedures

*When performing the deceleration measurement, a quick **build-up of brake pressure** must be observed. 90 % of the desired brake pressure must be achieved after less than 0.4 s. To ensure the repeatability of the test as well as the comparability of results, the **road friction coefficient** must have been determined, and the required **base temperature of the brakes** at the beginning of the braking maneuver defined. The duration of braking and the braking distance are defined as starting with the achievement of 5 % of the maximum brake pressure until the vehicle has come to a complete halt. The example shown here presents an ABS-controlled hard stop from a speed of 100 km/h until the vehicle comes to a complete halt.*

Measurands

*According to DIN 70028 the following “**mandatory measurands**” must be logged:*

- *Vehicle speed*
- *Time when braking begins*
- *Braking distance over the defined measurement duration*
- *Brake pedal force (or brake pressure in brake master cylinder)*

*In addition, logging of the following “**optional measurands**” is recommended:*

- *Wheel forces and moments*
- *Float angle, float angle speed*
- *Yaw angle, yaw angle speed, yaw angle acceleration*
- *Slip angle of the front wheels*
- *Trail angle of the front wheels*
- *Steering wheel angle*

GeneSys Elektronik GmbH
TÜV SÜD Automotive
CORRSYS DATRON Sensorsysteme GmbH
KISTLER measure. analyze. innovate.
worldwide DEWETRON

Selection of Measurement Systems to Determine the Relevant Characteristics from the “Straight-line Braking” Vehicle Dynamics Test:

Measurement Steering Wheel MSW

*The measurement steering wheel MSW by CORRSYS-DATRON was developed for **simultaneous data acquisition** of the **steering wheel turning angle**, **steering torque** and **steering angle speed**. The steering angle and the steering angle speed derived thereof are obtained by means of a non-contact, optical steering angle sensor. The steering angle can be measured in two measurement ranges (±200° or ±1250°) at an angular dissolution of 0.05°; for the steering angle speed, a range of ±1000°/s is available. The measurement steering wheel can be easily fitted to the steering column through a center hole; the assembly depth is relatively small. CORRSYS-DATRON article number: 14256.*

Wheel vector sensor RV4

*The wheel vector sensor by CORRSYS-DATRON is a **5-joint measurement arm with incremental turning angle sensors**. With the 5 angle settings in the joints and the known spaces between the joints it is possible to achieve a resolution of the **wheel position** in x, y and z direction (±150 mm, ±150 mm, ±200 mm) at an accuracy of approx. 1 mm. In addition, the wheel position is determined by camber and trail angle measurements (±10°, ±60° at an accuracy of 0.2° and 0.1°, respectively). The wheel angle sensor RV4 enables measurements of the positional shifts of the wheel center due to axle load shifts (single and combined load conditions of braking and accelerating), the positional change of the wheel center as well as toe and camber angle changes during lateral-dynamic driving maneuvers. In addition, a slip angle sensor can be attached with a snug fit to the wheel pivot of the RV4. CORRSYS-DATRON article number: 14619.*

Strap-Down Gyro Measuring Device with GPS

*The center piece of the ADMA strap-down inertial measurement platform by GeneSys consists of three fiber optic gyros used to **measure the rotational speed** around the x, y and z axis and 3 accelerometers for the three leveled coordinates. At the same time, the acceleration signals are used to analytically maintain the system in a leveled state by referencing the Earth gravity vector. The gyros enable all angles to be calculated in three dimensions. The major advantages of this system are **high bandwidth** (50...400 Hz), **low data latency** and the provision of all **translational and rotational state parameters** in three space axes, respectively. These are: acceleration, speed, position, rotational speed and angle, which are delivered as output in the onboard, leveled and earth-related coordinates system. With GPS support, drift errors are continually eliminated and with DGPS a **positional accuracy within the range of centimeters** can even be achieved. GeneSys article name: ADMA-G (Automotive Dynamic Motion Analyzer with DGPS).*

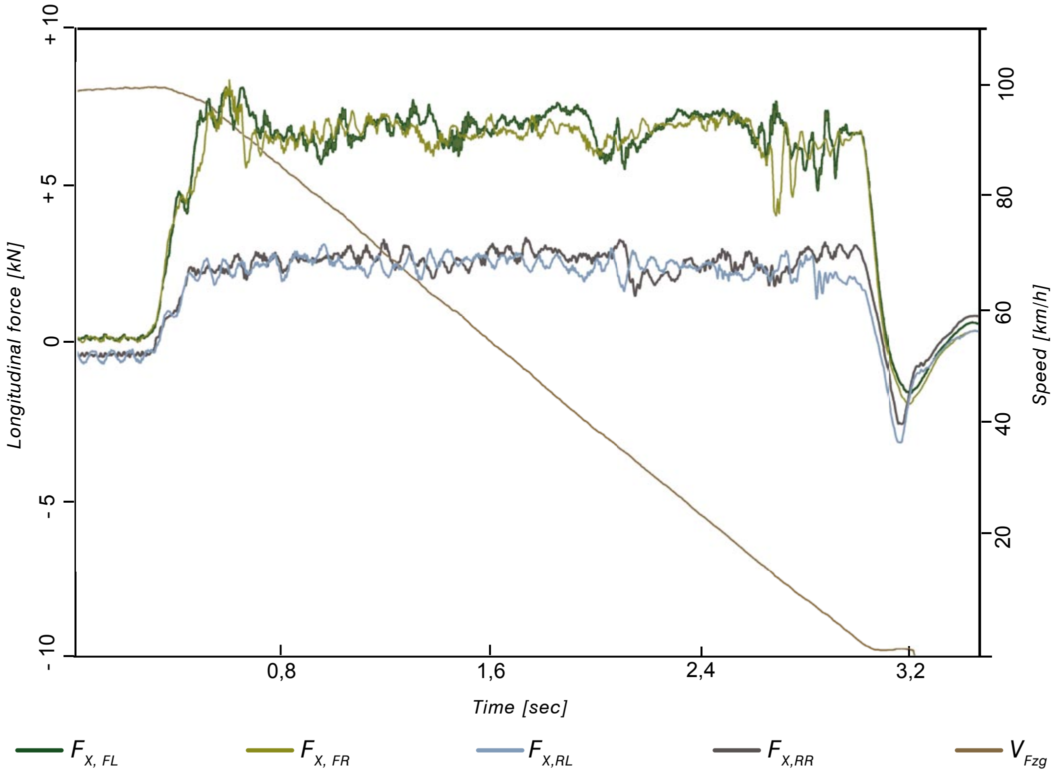
Wheel Force Dynamometer RoaDyn P650

*The wheel force dynamometer by Kistler is available in versions with DMS-applied dynamometers and stiff, biased piezoelectric measurement sensors. The RoaDyn P650 measurement system uses **piezoelectric measuring technology** and is characterized by a **high natural frequency** of up to 2 kHz and **high sensitivity** across the entire measurement range (F_x = 45 kN, F_y = 24 k, F_z = 45 kN). It is ageing-resistant and exhibits outstanding stability as well as high linearity. The wheel force dynamometer measures the **wheel force distribution** in circumferential, transverse and vertical directions as well as drive, camber and self-aligning torques. Data is transmitted by telemetry from the rotor to the stator and magnets inside the rotor enable the exact **determination of the wheel turning angle** by using the Hall effect. The onboard electronics system 2000 enables self-identification of the measurement wheel sensors used and performs online calculations of the aforementioned measurands. In addition, further analog signals can be connected to the wheel force dynamometer (e.g. temperature signals of the T^{3}M measurement system by TÜV SÜD Automotive). Kistler article number: 9298B1Q03.*

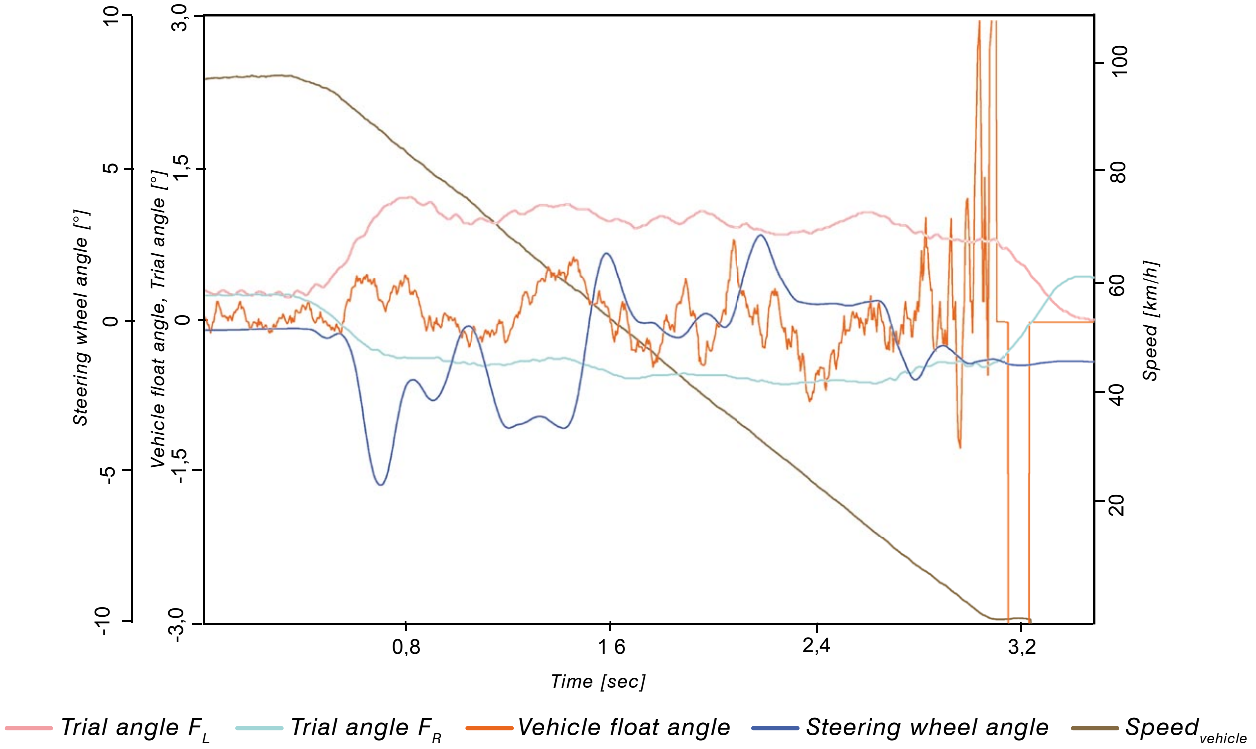
Synchronous Data Acquisition

*Synchronicity of the measured data is of crucial importance in all vehicle dynamics tests. Up to now, the data obtained by different sensors and sensor systems could only be correlated with each other with major error tolerances. The special feature of the data acquisition unit is the generation of a high-precision quartz-stabilized **system cycle with 80 MHz** and a **slope accuracy of 2 ns**. With this system cycle all measurements are synchronized and provided with a **real-time stamp**. In addition, the internal system cycle can be coherently (in-phase) coupled with an external cycle signal in order to make absolutely synchronous measurements using, for example, the pps signal of a GPS satellite. Besides analogous and digital information, various CAN-Bus systems, LAN and other **asynchronous interfaces are synchronized with the system cycle**. The video cameras used have an external cycle input with which each individual image is accurately timed, thus achieving exact synchronicity here as well. DEWETRON article name: DEWE-501.*

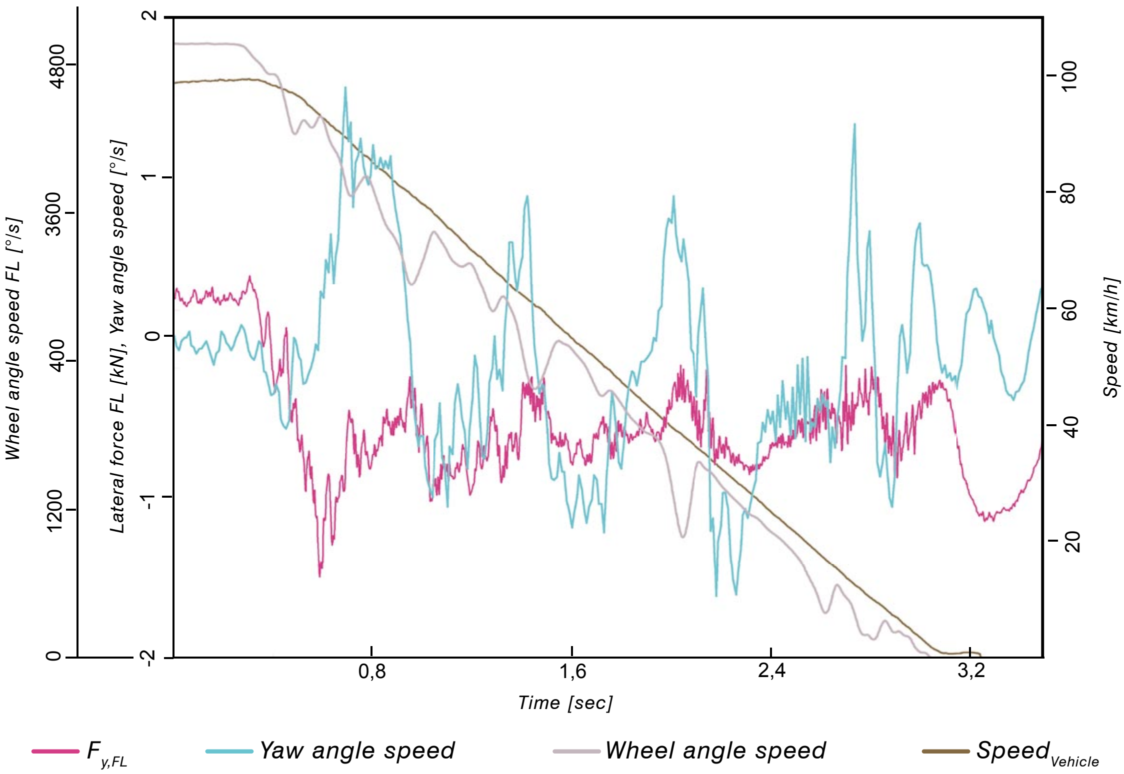
Data Analysis



*The diagram shows the **longitudinal forces** (deceleration forces) on all four wheels over the vehicle speed. The initial speed is **100 km/h** and a controlled **ABS braking maneuver** with maximum brake pressure is performed until the vehicle comes to a complete halt. The brake force ratio between the front and rear axles, according to conventional design, is approx. 3:1. All four wheels are subject to anti-locking control, which means that just before the locking limit is reached, brake pressure is reduced. This decreases the longitudinal force which increases again shortly afterwards as brake pressure increases again. Readings of 12-13 control events per second are provided. The value of approx. **10 m/s^2** was measured as the **average brake deceleration**.*



The **toe-in angles of the front wheels**, set at approx. 10’ when performing the wheel alignment, increase in the opposite direction by approx. ±1° from the beginning of the ABS braking maneuver and thus significantly contribute to straight-line stabilization. The **vehicle’s float angle** fluctuates around maximum values of ±1°. Higher values occur only when the vehicle jolts shortly before coming to a halt. However, they have no relevance to vehicle dynamics. The steering angle curve, which is merely in the range of ±1° around the zero-degree position, is a further indication of directional stability under braking. The front wheel slip angles and the lateral forces exhibit the same characteristics as the toe-in angles.



The wheel angle speed curve in this diagram shows the **effectiveness of the control interventions**. Wheel speed repeatedly increases as brake pressure drops and then continually decreases as the deceleration force increases. The time curve of the front left lateral force and the yaw speed shows the phase delay of the yaw speed, which results from the vehicle’s inertia. The absolute values measured for yaw speed are ±1.5° and indicate **very good vehicle stability**.

Summary

Characteristic parameters for the **deceleration ability** of a vehicle include, for example:

- Braking distance as a function of initial speed or
- Average deceleration as a function of brake pressure.

The **average braking deceleration** when braking from the initial longitudinal speed $v_{x,0}$ and the braking distance $s_{B,x}$ until the vehicle has come to a complete halt can be calculated to:

$$a_x = \frac{{v_{x,0}}^2}{s_{B,x}}$$

To evaluate **vehicle stability** and **directional stability**, the following characteristics, for example, are known from literature:

- Lateral deviation across the braking distance
- Yaw speed across the duration of braking (average deceleration)