Driveability Test Maneuver:

Braking from Steady-State Circular Motion

Fahrdynamik Test Allianz
DTA
Driveability Testing Alliance

Objective of the Driving Maneuver

*According to ISO 7975 this open-loop test serves the main objective of determining **the effect of braking on the directional behavior** of a vehicle whose steady-state circular motion is only interfered with by the response of the brake.*

*Similar to the situation that occurs during load alteration the vehicle tends to turn toward the inside of the corner, which forces the driver to perform **quick steering corrections**. The **float angle** measured during this driving maneuver provides **conclusions about driving stability and controllability** of the vehicle.*

Test Procedures

*The vehicle is driven on a **circle with a radius of 100 m** at **constant lateral acceleration**. In the example shown here, lateral acceleration is **7 m/s²**. The steering wheel angle and accelerator pedal position must be kept constant in the test. The braking maneuvers are driven with longitudinal decelerations of 2 to 6 m/s² in steps of 1 m/s² counter-clockwise and clockwise, in third gear. At the beginning of the maneuver the driver has to **lift the accelerator** pedal as fast as possible and **immediately apply the brakes**.*

*The time span until the longitudinal deceleration of 0.5 m/s² is exceeded has to be < 0.4 s. At the time of t_0 a pressure of 90 % of its mean value must be achieved. According to the **analytical routine developed by TÜV** the values for the established measurands from the time of 0.9 s up to the end point of 1.1 s after initiating the actuation of the brake are averaged and stored per braking event. The values of the measurands for the steady-state range, the analysis time frame as well as the maximum values are read out, and the various characteristic values determined from them. The **deviations from the original cornering radius** and the **maximum float angles per longitudinal deceleration** step are of particular interest.*

Measurands

- *Steering wheel angle*
- *Brake pressure in brake master cylinder (alternatively brake pedal force or travel)*
- *Lateral acceleration*
- *Longitudinal acceleration*
- *Longitudinal speed*
- *Yaw speed*
- *Braking distance*
- *Roll angle*
- *Pitch angle*
- *Float angle*
- *Lateral speed*
- *Lateral deviation of the vehicle's center of gravity from the initial radius*

Selection of Measurement Systems to Determine the Relevant Characteristics from the " Braking from Steady-State Circular Motion" 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.*

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 three 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 1 kHz and **high sensitivity** across the entire measurement range (F_x = 24 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^3M measurement system by TÜV SÜD Automotive). Kistler article number: 9298B1Q03.*

Pitch and Roll Angle Measurement System

*The measurement system is based on the distance measurement of 3 select vehicle body points vis-à-vis the road. The **pitch angle** θ is the angle between the vehicle's longitudinal axis and its projection to the road, the **roll angle** φ is defined as the angle between the vehicle's transversal axis and its projection to the road.*

The θ and φ angles can be calculated as arctan functions from the trigonometric distance relationships. For the speed range of 0 – 250 km/h, the measuring range for the pitch and roll angle is ±40° at a resolution of 0.1°.

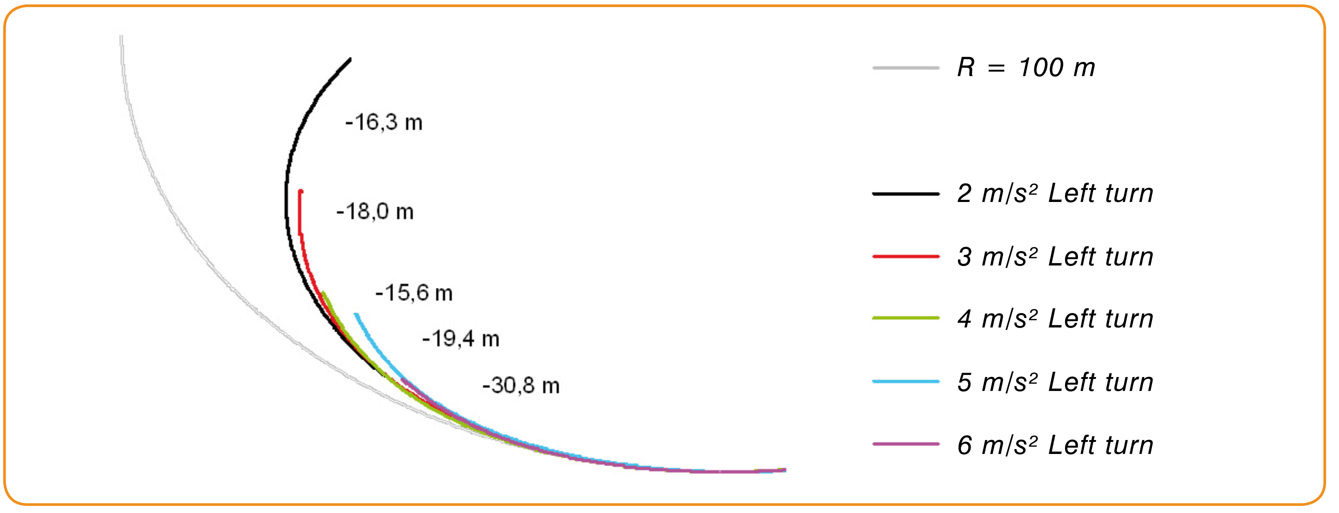
*The HF 500 C height level sensor by CORRSYS-DATRON operates according to the **optical triangulation principle**. A visible red laser is projected onto the object and the reflected light is represented on a CCD line. If the direction of the beam and the distance between the CCD line and the light source are known, the distance between the object and the CCD line can thus be calculated using a signal processor. The distance between the CCD line as well as the two beams from and to the object form a triangle (triangulation). CORRSYS-DATRON article number: 15380.*

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.*

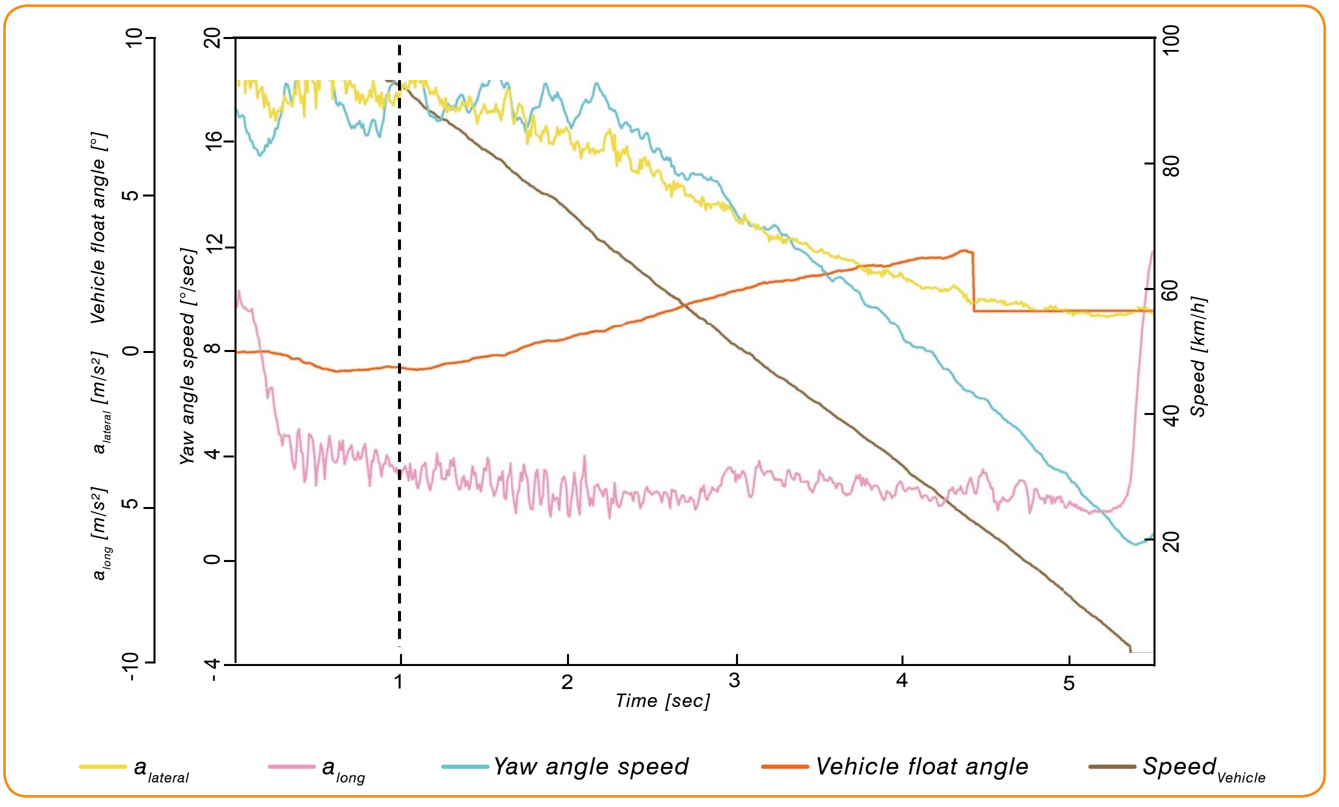
Data Analysis



Braking with deactivated DSC from Steady-State Circular Motion at constant lateral acceleration of 7 m/s²

The diagram plots the relevant measurands for the "Braking from Steady-State Circular Motion" driving dynamics test over time. These are: longitudinal and lateral acceleration, yaw rate, float angle and longitudinal speed. The analysis time frame of 0.9 – 1.1 s is related to the ***trigger signal of the brake light switch*** *and marked as a 1-second value in the diagram. The values for the steady-state range before braking and for the analysis period are entered into a tabular chart for all trials. In addition, the maximum values which occurred and – as a characteristic value to be highlighted – the deviation of the* ***radius from the reference circle are indicated****.*

In accordance with the float angle characteristics from the steady-state circular test a ***negative float angle*** *occurs at high lateral acceleration whose* ***polarity changes to the positive*** *range with decreasing lateral acceleration after zero crossing. Because the float angle is calculated from the arctan relationship between lateral and longitudinal speed the signal is set to zero at a vehicle speed of ≤5 m/s.*



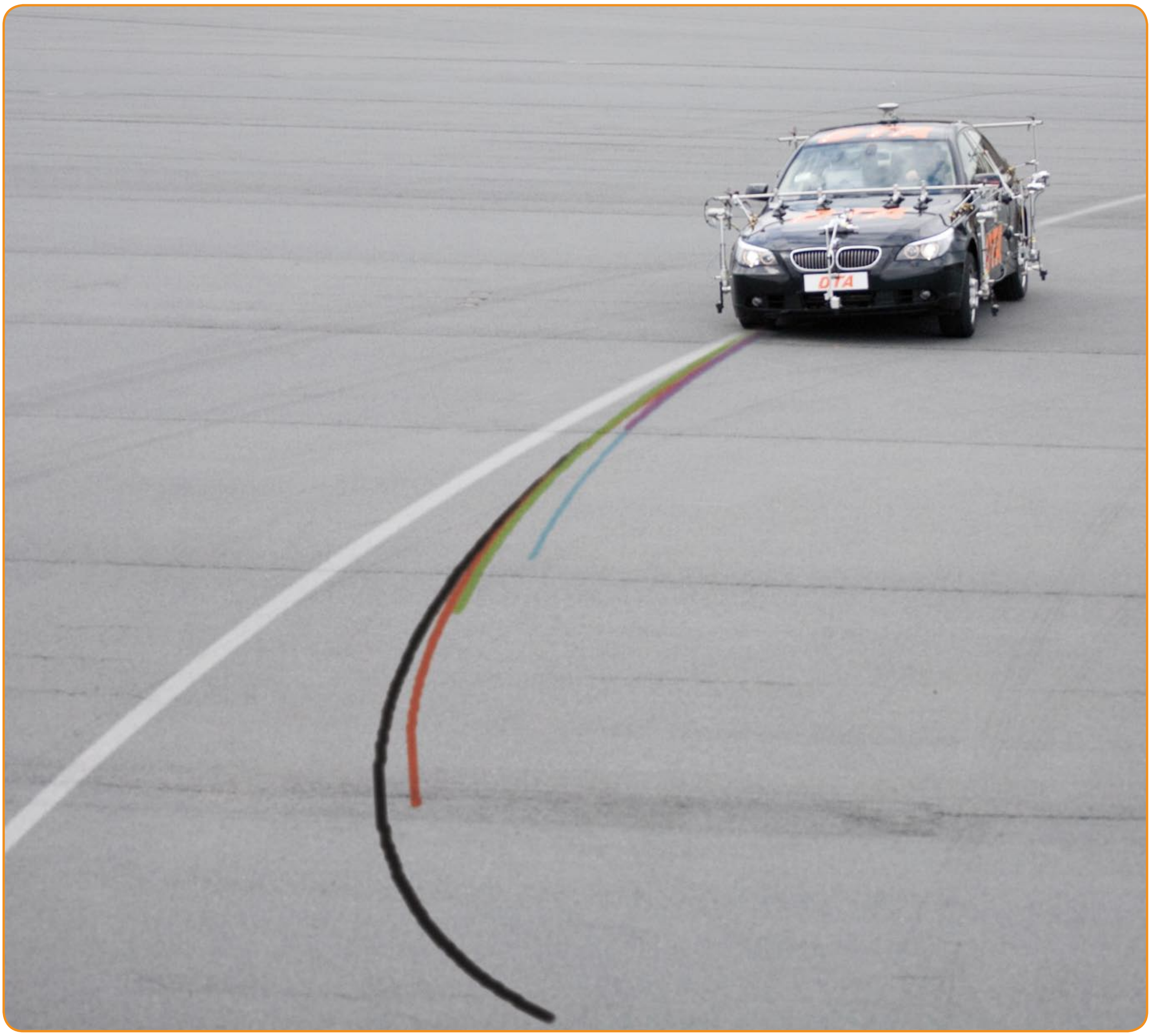
The **deviations from the reference circle** with the radius of 100 m at an initial acceleration of 7 m/s² are plotted in the diagram and backed by numerical values. With significantly increasing longitudinal deceleration the deviation exponentially increases in the final range. The **float angles** stated additionally, measured 1 s after braking starts, remain within relatively narrow limits and are a measure for existing **driving stability** and good **controllability of the vehicle**.

Summary

According to Heissing/Ersoy in **braking events up to mean decelerations** a **maximum yaw moment** occurs when the longitudinal forces in the tire contact patch change due to shifting wheel loads. The **higher wheel loads** lead to a reduced slip angle at the front axle and an increased slip angle at the rear axle. This causes the **instantaneous center of rotation** vis-à-vis the position in the un-braked state to significantly shift forward and closer to the vehicle, thus resulting in a smaller cornering radius.

At **maximum deceleration** the effect is determined by the locking sequence of the wheels and thus by brake force distribution. However, when ABS is used this differentiation is no longer relevant.

The evaluation of vehicle response primarily refers to the lateral deviation from the previously maintained reference direction and the dimension of the float angle, and thus yaw stability.



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