The OMS 7 sensor mounted on the tow hook of a Mercedes

SLIP NO MORE

When Mercedes-Benz needed a high-precision vehicle dynamics test solution, it chose Sensoric Solutions as its partner

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The development of a vehicle begins with an idea, the identification of a need or the realization that there's a problem that needs solving. Today, a significant portion of the development process takes place digitally. Designs are created, integrated and validated through virtual test drives. Only after successful simulation runs does the vehicle dynamics testing commence under real-world conditions. During this phase, vehicles are tested globally under a wide range of conditions to identify and resolve even the smallest weaknesses before series production.

Particularly in vehicle dynamics testing, a multitude of parameters must be measured with the utmost precision. For the test engineer, it is essential that measurement technology and equipment are not only reliable but also efficient to meet the increasing demands of development and testing procedures.

At Mercedes-Benz, development of the brand-specific driving character is a central focus. This is defined by a variety of vehicle dynamics parameters that determine how a Mercedes should feel while driving. To achieve this, these parameters are precisely measured during testing and compared with target specifications.

Accurate measurement of a vehicle's dynamic state is of paramount importance, as the quality of the measurement signal directly influences the reliability of the parameters and, ultimately, the achievement of the Mercedes-Benz driving character.

One critical parameter in vehicle tuning is the vehicle's slip angle. This represents the difference between the vehicle's longitudinal axis and the velocity vector at a defined point of measurement. It provides valuable insights into tire and axle characteristics as well as general stability criteria. With advanced chassis systems such as rear-wheel steering, the measured slip angles can become very small. In such test cases, high resolution and accuracy are fundamental. Only with precise slip angle measurements can nuanced adjustments be made to the vehicle, ensuring the Mercedes-Benz driving character is achieved.

The package developed for Mercedes-Benz combines non-contact, optical technology with an IMU

The slip angle is a location-dependent physical quantity, requiring conversions to specific reference points, such as the vehicle's center of gravity or the rear axle, for accurate vehicle dynamics analysis. This enables objective comparisons between vehicles. For these conversions, a stable measurement signal is required to avoid numerical artifacts unrelated to driving physics.

The generation of objective parameters relies on capturing low-noise, accurate measurement signals as the foundation. Slip angle measurement has traditionally been prone to high levels of noise due to optical measurement techniques and subsequent transformation using Fourier analysis. As a result, statistical methods and extended data recording were needed to stabilize the slip angle signal quality. This led to a trade-off between noise suppression and dynamic filtering, particularly during dynamic driving maneuvers.

New optical sensor
Sensoric Solutions' newly developed OMS 7 sensor introduces an innovative approach to measuring vehicle dynamics by integrating two key technologies: optical spatial filtering – a non-contact optical technology that enables precise measurement of parameters such as vehicle speed and slip angle; and an inertial measurement unit that incorporates accelerometers and gyroscopes and captures detailed data on the vehicle's accelerations and angular rates.

By combining these technologies, the OMS 7 sensor provides accurate, comprehensive data on various vehicle dynamics parameters, including vehicle speed, slip, pitch and roll angles, as well as accelerations and angular rates.

Optical spatial filtering method
The optical method of the OMS 7 uses infrared LED illumination that projects onto the road surface. The reflection from the textured surface of the road is captured through a lens system onto a grid-shaped photodiode array. A deflecting mirror redirects the incoming light, enabling a compact design.

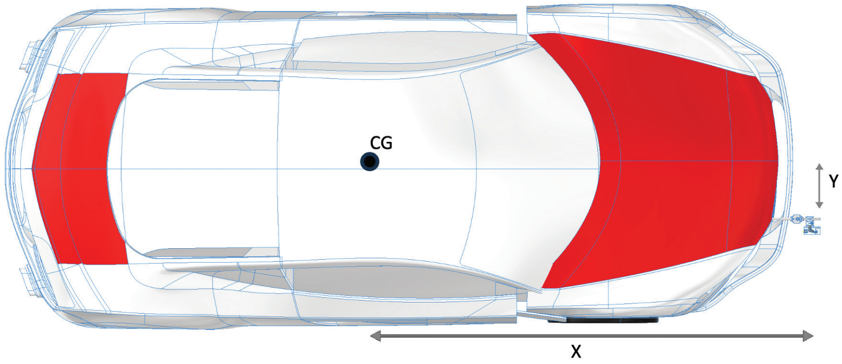
When the sensor moves above the road surface, individual texture points of the ground pass over the individual diode surfaces. Each time a texture point crosses a diode surface, an electrical voltage is generated.

The resulting signal resembles an amplitude-modulated sinusoidal wave. The amplitude of the signal depends on the reflection from the surface and is subject to significant fluctuations, rendering it unsuitable for directly determining parameters. However, the frequency of the signal is proportional to the speed of the vehicle.

To measure lateral speed, the photodiode array incorporates additional diodes. These diode surfaces are positioned at a 90° angle to each other and at a 45° angle to the direction of travel.

During straight-line motion, the frequencies from both halves of the photodiode array are equal. When the vehicle moves in a curved path, the texture points pass over the diode surfaces at an angle. This causes one frequency to decrease while the other increases. Using the ratio of these two frequencies, the velocity vector can be determined using trigonometric formulas. A subsequent calculation enables the longitudinal and lateral speeds to be determined.

For more on the benefits and drawbacks of optical technology, see *Optical technology insight*, below.



Vehicle mounting and geometric measurement of the points of interest

Fusion of technologies
In the OMS 7, optical technology and inertial measurement unit technology are combined. The fusion of optical signals and IMU data offers significant advantages. For example, the long-term stability of optical signals enables precise measurement of motion parameters without drift or offset, and the highly dynamic data from the IMU enables accurate capture of rapid, changing motion sequences.

By combining the characteristics of an IMU (see *IMU characteristics explained*, p97) and optical technology, a highly precise sensor system with minimal signal noise is created. Additionally, extensive post-processing of data is

Comprehensive measurements of vehicle movements can be carried out with this cutting-edge sensor solution

Optical technology insight

Sensoric Solutions' OMS 7 uses the optical spatial filtering technique. This technology offers multiple beneficial features.

Advantages of optical technology
- Contactless, slip-free measurement principle: Ensures precise measurements without reliance on wheel-slip-sensitive methods;
- Operation on nearly all surfaces: Functions effectively on various road textures, including challenging conditions;
- Reliable and proven technology: Widely accepted and validated in dynamic measurement applications.

Disadvantages of optical technology
- Limited resolution for path measurement: The system's ability to measure exact displacement or detailed path tracking is constrained due to the limitations of optical resolution.

IMU characteristics explained

An IMU is a complete inertial system consisting of a three-axis gyroscope and a three-axis accelerometer. The three-axis configuration enables vector-based determination of rotational rate and acceleration in space. The type used here is a MEMS-based (micro-electromechanical system) IMU. This technology integrates miniaturized mechanical and electrical components on a microchip. Depending on the chip used, the size is only a few millimeters, enabling it to fit alongside the optical components within the sensor.

Advantages of the IMU
- High-dynamic system: Capable of capturing rapid changes in motion and orientation;
- High bandwidth: Processes a wide range of motion frequencies effectively;
- High output rates: Provides real-time data with fast sampling speeds.

Disadvantage of the IMU
- Signal drift or offset: the data is subject to gradual inaccuracies over time, requiring correction or calibration.

no longer necessary as motion parameters are measured directly. For example, vehicle speed and slip angle are measured with a high accuracy of up to 0.1%. Integration and offset errors are eliminated.

The measurement of accelerations and rotational rates is also performed directly via the integrated IMU platform. After the installation and alignment of a single OMS 7 sensor, the test engineer has access to more than 40 signals, enabling precise analysis of a vehicle's motion state.

"With its large working range of 300mm ±150mm, the OMS 7 is highly versatile"

To handle highly dynamic applications, such as lane-change maneuvers, the sensor operates with a sampling rate of 1kHz.

The sensor fusion implemented by Sensoric Solutions provides Mercedes-Benz with the advantages of low-noise, real-time-capable measurement of the slip angle. A significant benefit is that it addresses the error component of the slip angle signal caused by vehicle body movement. This is achieved through a correction function that detects and compensates for the roll motion. This is particularly critical during vehicle testing as the objective is to analyze the slip angle of the rigid-body vehicle under planar motion conditions. This ensures that measurements accurately reflect the true dynamics of the vehicle, free from interference caused by body roll or other non-planar movements.

Features of the new sensor

Thanks to the integrated real-time computation, the measured accelerations and rotational rates can be captured not only relative to the ground but also transformed into leveled signals. Additionally, calculated signals enable the flexible translation of the measurement point to any desired location on the vehicle by specifying the sensor's position relative to that point. This is easily achieved by entering the sensor's coordinates via the integrated web interface, providing unparalleled convenience and adaptability during testing and data analysis. This capability ensures precise alignment of data to critical vehicle reference points, enhancing the accuracy and relevance of the measurements.

This is particularly relevant because the sensor's mounting location often does not coincide with the location of the desired measurement parameter. Since all measured values – except for rotational rates – are location dependent, accurate conversion is critical for evaluating vehicle dynamics data. The OMS 7 provides the engineer with more than 40 signals in a flexible and user-friendly manner, available via CAN or ethernet streams. This ensures maximum freedom in vehicle dynamics analysis.

Furthermore, the OMS 7 can be easily mounted almost anywhere on the vehicle. A wide range of mounting options – including suction cups, magnets and specific attachments for the tow hook or wheel – ensures flexible and straightforward installation.

With its large working range of 300mm ±150mm, the OMS 7 is highly versatile and suitable for a wide variety of vehicles, from passenger cars and trucks to motorcycles.

The configuration of the OMS 7 is performed via an ethernet interface connected to the sensor's ECU. Using a web interface, all settings and calculations can be conveniently managed without the need for additional software installation. In addition to configuring sensor parameters, the ECU handles all signal filtering, processing and conversion. A standout feature is the ability to output the raw optical signals and the fused measurement signals, offering unparalleled flexibility in data use and analysis.

With the OMS 7, Mercedes-Benz gains the ability to measure and evaluate objective parameters with greater accuracy and repeatability. Furthermore, new

Last year, OMS 7 was shortlisted for Hardware Innovation of the Year in the ATTI Awards