

CORREVIT[®] Optical Sensor Technology: Focusing on the Future

In 1982, when the world's first optical speed and distance sensor was introduced, few could have predicted the impact that this breakthrough technology would have on the discipline of vehicle testing. Over the course of more than two decades, the CORREVIT[®] Sensor has become the standard for accuracy in the measurement of vehicle dynamics. Today, the evolution of the CORREVIT[®] Sensor continues at CORRSYS-DATRON, with new refinements and new applications that are certain to again re-define the state of the art in measurement instrumentation.

The convergence of local and global positioning systems

It is a fundamental principle that wheel slip is inherent to the transfer of driving or braking forces from the vehicle tire to the surface of a test track or highway. Therefore, what on one hand is favorable to the ability to control a car, will on the other hand, introduce systematic errors into wheel-dependent measurement systems (e.g. wheel pulse encoders).

So how then can vehicle-testing engineers measure *true* two-dimensional velocity, *true* maximum velocity or *true* braking distance? It is obvious that self-referenced, wheel-dependent sensors cannot be the solution. For true and accurate distance measurements, it is necessary to relate vehicle motion to a fixed reference frame.

The Global Positioning System (GPS) offers one solution, but in order to provide a reliable global reference frame, GPS requires an unobstructed line-of-sight with a minimum of 5 - 7 satellites. Unfortunately, every obstruction (by buildings, trees, tunnels, etc.) in the line of sight between available GPS satellites and the GPS receiver can prevent available signals from reaching the receiver. Further, because GPS satellites are not stationary in their orbits, the GPS reference frame is not stationary in time.

Complicating the situation even more is the fact that, as the number of available satellites varies, so too will the available accuracy of the GPS system. As logic dictates, any reduction in the number of acquired satellite signals will produce a corresponding reduction in measurement accuracy.

Given these facts, the advantages of having a local reference frame become obvious. So how then is the local reference frame established? Again, the answer is abundantly evident: the only true frame of reference available to a moving vehicle is the surface of the road or test track.

Having established the reference frame, the single issue that remains is that of identifying a means by which the desired variable set can be measured. In this case, the required instrumentation would be classified as a **Local Positioning System, or LPS**, a term that precisely describes the function of the CORREVIT[®] Optical Sensor.

CORREVIT[®] Optical Sensors effectively fulfill the requirements of local positioning measurement via a specialized optical grating system. As the measurement surface moves relative to the sensor, stochastic details of the surface microstructure move transversely, across the prismatic grid of the optical grating component, producing a modulation of the photocurrent. The sine-like periods of the modulating signal represent an average distance (or length). When counted, these periods are used to calculate the traveled distance.

Thus, a CORREVIT[®] Sensor is essentially a length/distance sensor. By using the known time interval during which the corresponding segment of the distance signal is acquired, it is a straightforward process to accurately calculate the momentary velocity. This is in stark contrast to GPS: positions are calculated from time-of-flight measurements, and distances must then be deduced from these position measurements.

There are, of course, a few points to be considered when using CORREVIT[®] Sensors. Because the CORREVIT[®] Sensors measure relative motion between a diffusely illuminated surface and the optical grating, any motion that occurs between the sensor and road surface can potentially cause systematic measurement errors. Real-world examples that can produce this effect are flying snowflakes and water spray.

Additionally, if the measurement surface is covered by water, specular components of the light reflected from the water layer can decrease the intensity of the optical signal. Intensity may also increase as light is reflected directly back to the sensor from the flanks of the small waves created as the vehicle tires disrupt the water on the test surface. This effect can be remedied by mounting the sensor away from water spray and tire-bow waves, e.g. in the middle of the front bumper.

Also functioning to eliminate this effect is an updated illumination technique now incorporated into CORREVIT[®] Sensors: a pair of newly developed halogen lamps that are configured to produce an exceptionally tight radiation angle. This new generation of CORREVIT[®] Halogen Lamps benefits from a special vapor-deposition process that enables use of the infrared component present in the halogen light source. In comprehensive testing, the near-infrared (NIR) component is proven to increase measurement accuracy, due to the fact that NIR is absorbed – rather than reflected – by water. The newly developed CORREVIT[®] LF Sensor incorporates NIR light-emitting diodes as an illumination source, and has proven to be highly successful in all testing environments.

In sum, because CORREVIT[®] Sensors offer the only measurement technique that relates directly to the measurement surface – which is only reasonable ubiquitous and stationary reference frame – they must be considered as the *only* true and objective instruments for **real-world vehicle dynamics testing**.

GPS indeed has value, but primarily as a low-dynamic backup for highly dynamic optical sensors. A combination of the two principles in an LPS-GPS sensor system is now in development at CORRSYS-DATRON. Combining CORREVIT[®] optical technology (for dynamic real-world measurements) with satellite navigation (for recording of absolute position), this new generation of sensors promises to be the most precise and powerful measurement tool yet devised for vehicle testing.

The shapes of things to come

Today, many state-of-the-art vehicles are equipped with driver assistance systems. However, even the most advanced of these systems are essentially blind to real-world dynamics data. At present, literally every dynamic parameter required by ABS and ESP systems is acquired via indirect measurement systems that use extensive software modeling to simulate and estimate actual conditions.

Imagine the power of a miniaturized, mass-production sensor that could provide real dynamics data – not data modeled from algorithms. This is precisely what the upcoming generation of CORREVIT[®] Sensors will do!

Because the CORREVIT[®] Sensors acquires measurements directly from the real world, the potential exists to measure far more than speed- and distance-related parameters. While the periodicity of the signal is determined by the incorporated optical grating, its amplitude distribution (the so-called power spectrum), and the degree of modulation of the CORREVIT[®] signal contain actual information about the **texture of the measurement surface**.

This information opens the way to a wide range of new applications. For example, the capacity to characterize surface structure will enable precise quantification of changes in the road surface during braking-distance measurement. These data will enable measurement of the **coefficient of friction** in the tire-road contact area, thus providing conclusive data about the tire-grip potential of the surface. By simultaneously correlating these data with accurate braking-distance measurement data, a truly unprecedented view of dynamic vehicle behavior is produced.

The CORREVIT[®] signal contains contributions from both the sensor and the surface. Figure 1 shows three different road surfaces: concrete, concrete pavement, and asphalt. Figure 2 shows what happens when the ratios of the signal power spectra are computed for each of these surfaces.



Fig. 1. Three different road surfaces. From left to right: concrete, concrete pavement, asphalt.

The respective spectra were derived from CORREVIT[®] signals with a Fast Fourier Transform (FFT). Higher frequencies in the spectrum correspond to smaller structural components of the surface; lower frequencies to larger ones. The ratios of the spectra do not contain contributions of the sensor itself, because its transfer function is cancelled out.

The spectra show that the structural components of asphalt and pavement are very similar in the range below approximately 1 cm, whereas concrete and pavement significantly differ from each other, except for structural components in the range of 3 mm to 6 mm.

Much theoretical work has been done to find a correlation between surface structure and the coefficient of friction between tire and road. An optical sensor monitoring the surface structure alone will not yield the coefficient of friction, but it will be able to predict the **maximum tire grip potential** of the surface. The technique described above was therefore applied during measurement of brake path lengths.

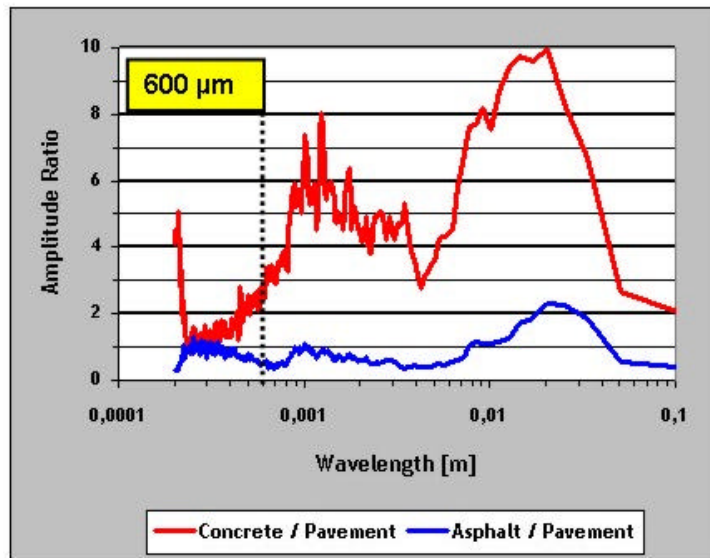


Fig. 2. Ratios of spectra for three different road surfaces. Grating constant of the sensor: 600 μm .

In Figure 3, the correlation coefficient between three different surface signal spectra is plotted against the respective brake path lengths. When the data are correlated to asphalt (as a high-friction surface), low-friction surfaces (gravel and soil + gravel) yield longer brake path lengths and lower correlation coefficients.

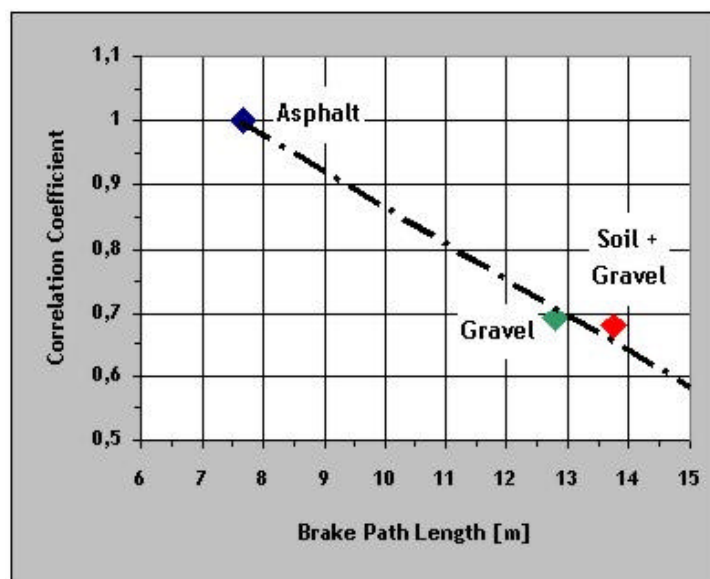


Fig. 3. Correlation coefficients of surface spectra plotted against respective brake path lengths.

The assessment of maximum tire-grip potential will be important not only for vehicle testing, but for road construction as well. In the near future, construction contracts will specify a required coefficient of friction for road surfaces. Traditional measurement techniques (e.g. SCRIM: Sideways Force Coefficient Routine Investigation Machine) are time-consuming, expensive and offer limited reproducibility. At present, the surfaces of airport runways are monitored in the same way. The CORREVIT[®] Non-Contact Optical Surface-Texture Sensor will, in the very near future, replace these techniques with a small, easy-to-use sensor that will function effectively, even at high velocities.

In measuring tire-grip potential, the road surface texture itself is but one consideration. Also important is the presence of ice, snow, and/or water upon the road surface. In response to this need, CORRSYS-DATRON has begun to develop an optical sensor that detects, and can **discriminate between ice, snow, and water present upon a road surface**.

The potential offered by the upcoming generations of CORREVIT[®] Sensors is immense. From increased accuracy in dynamic testing instrumentation, to sensors that will improve and enhance driving safety, CORRSYS-DATRON continues to build on its longstanding tradition of innovation in the field of **objective, real-world measurement technology**.