New laser line sensor for high-speed pavement profiling

A new family of high-speed laser line sensors has recently been developed and installed on high-speed and lightweight inertial profilers to improve surface measurement accuracy on coarse textured concrete pavement. While thousands of laser triangulation sensors have been used on profilers for over 30 years, the introduction of coarse textured pavements presented measurement challenges to these earlier generation measurement sensors.

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Figure 1: Laser line sensor for profiling.

The traditional point triangulation sensors provided reliable, high-speed measurement data every millimetre along the road at highway speed on a lot of typical road surfaces.

As point triangulation sensors have a small laser spot at the pavement surface, they measure a lot of detail when profiling. This process works well on transversely-tined pavement as the wavelengths of the transverse tines are much smaller than the roughness wavelengths that the users are interested in.

However, when pavement is longitudinally-tined or there are other longitudinal features (grooving, grinding, material drag), the small laser spot can creep up on a ridge or fall into a valley at any frequency depending on the drive path of the vehicle. This can create false roughness at longer wavelengths that cannot be separated from the 'true' roughness that the tyre (and ultimately, the vehicle) experiences.

Studies commissioned by ACPA (American Concrete Pavement Association) and carried out by UMTRI (University of Michigan Transportation Research Institute) determined that profiler performance with simple single point laser sensors needed improvement on coarse textured concrete surfaces to be acceptable for use in construction quality control. Improvements were particularly needed for longitudinally tined pavement and on other coarse surfaces.

Inertial profilers are complex systems of many integrated elements (laser and other sensors, filters, analysis software, the mechanical platform and the operator), all of which must perform properly to obtain accurate results. Analysis showed that the profiler performance issues on coarse textured surfaces would best be addressed by making improvements to the laser sensor technology used.

The laser line sensor solution

To provide accurate data when profiling coarse textured pavements, a new type of laser line sensor was developed. Laser line sensing provides the ability to measure the surface at hundreds of points across the laser line. While line sensors had been used in other industries, the challenge for profiling was to develop a very high-speed sensor to operate at highway speed, provide accurate data from a wide variety of materials, and maintain accuracy in a broad range of environments such as bright sunlight to dark shadows, be rugged to survive shock and vibration and provide easy integration for the profiler manufacturer.

The resulting sensor, known as the RoLine 1130, is shown in Figure 1. It measures across a 100mm line, similar to a typical tyre width, taking thousands of line profiles per second. It is a 'smart sensor', with all measurement functions (triangulation calculations, linearisation and conversion of data to engineering units) carried out inside the sensor head. This eliminates the need for profiler manufacturers to be concerned with any of these issues; they only need to connect the sensor output to their host computer.

To provide flexibility for the profiler manufacturer, the sensor has two data output modes: either full profile data or the optional output using the internal bridging algorithm, which reduces the full profile to a single

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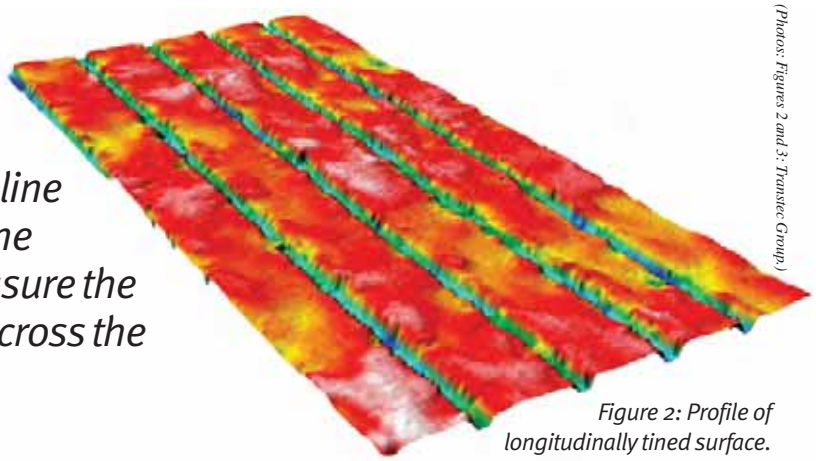

Figure 2: Profile of longitudinally tined surface.

(Photos: Figures 2 and 3: Transtec Group.)

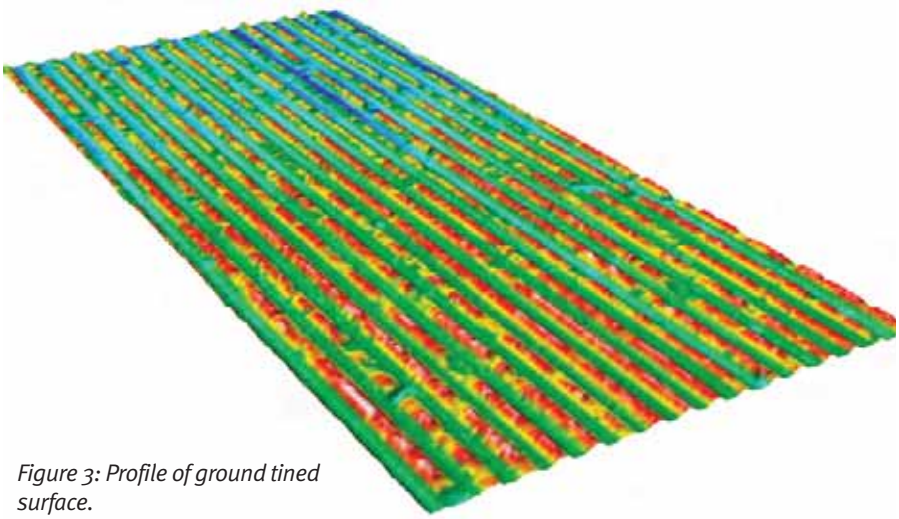

Figure 3: Profile of ground tined surface.

point output representing the actual surface location. The full profile mode provides the profiler manufacturer with the ability to process the information with their own proprietary analysis. The bridged value output is useful when retro- fitting the sensor to older systems equipped with point measurement sensors.

To facilitate easy transfer of high-density sensor profile data to the profiler system, the sensors are provided with Gigabit ethernet output. Use of an industrial standard communications protocol simplifies the task of the profiler manufacturer, eliminating the cost and risk of developing customised communications interfaces.

Sensor test results

To validate the laser line sensor performance, a series of tests were performed in a variety of conditions. The Transtec Group installed a laser line sensor on their RoboTex measurement system and tested operation on a variety of coarse textured surfaces. The tests were performed at low speed, showing the sensor's capability to provide very dense surface 3D data.

Figure 2 shows the 3D data from a longitudinally tined surface and Figure 3 is from a ground tined surface. These examples show that extremely detailed 3D information is obtained with the laser line sensor, providing surface detail that had not been seen previously.

ACPA sponsored testing of the new laser line sensors on a number of different profilers, on a variety of coarse textured concrete pavements. The sensors demonstrated vastly improved repeatability and cross-correlation on all the test pavements, including longitudinally tined and ground surfaces.

Conclusion

The implementation of laser line sensing technology has improved the repeatability and accuracy of profiling coarse textured concrete pavement surfaces of all types. Taking thousands of line profiles per second meets the need of high-speed profilers to operate at highway speed. The increased data density provides detailed 3D profiles of the pavement, improving the reliability of data on all surfaces when implemented on both lightweight and high-speed profilers. ■